HORIZONTAL PLANUM TEMPORALE OF THE HUMAN BRAIN AND ITS RELATIONSHIP WITH PHONOLOGICAL PROCESSING AND EMERGENT READING SKILLS IN YOUNG CHILDREN

By

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This study examined relationships between asymmetry of the horizontal planum, located in the temporal lobe of the human brain; and phonemic awareness, emergent reading skills, and rapid naming skills in children ages five through seven. Data were acquired by using magnetic resonance imaging (MRI) to measure the horizontal planum temporale and through psychoeducational tests to assess phonemic awareness, emergent reading, and rapid naming. Additional data were acquired on children's intelligence, handedness, developmental history, and socioeconomic status. A series of explanatory multiple regression models was conducted for each of the three construct skill families (i.e., phonemic awareness, emergent reading, and rapid naming) to determine if horizontal planar asymmetry predicted these skills. A Bonferroni adjustment was applied for each construct family.

In reference to phonemic awareness, two of the three equations were significant. Horizontal planar asymmetry accounts for 29% and 21% of the variability in the scores from measures of phoneme manipulation and auditory closure for missing phonemes, respectively. The third equation, another measure of phoneme manipulation, was not significant. The control variables, particularly IQ and gender, accounted for all or most of the variability in scores.

In reference to emergent reading, three of the four variables produced significant equations, thus suggesting that horizontal planar asymmetry predicts basic reading skills. Horizontal planar asymmetry explained 32% of the variance on a measure of sight word reading, 25% of the variance on an index of early reading skills, and 23% of the variance of reading comprehension. An equation examining the relationship between horizontal planar asymmetry and reading phonetically regular nonsense sight words was not significant. Thus, the horizontal planum temporale was strongly related to emergent reading skills in a sample of young children.

In reference to rapid naming, the equations were not significant. This suggests that the neuropsychological processes associated with these skills are not located in the horizontal planum.

CHAPTER 1
INTRODUCTION

Phonemes consist of individual sounds of language. Moreover, phonemes often are represented by letters or letter combinations (Palincsar & Perry, 1995). Phonemic awareness occurs when one is consciously aware of these sounds, one is aware that words consist of phonemes, and one has the ability to use this knowledge of phonemes when reading and spelling (Snider, 1995; Snider, 1997).

English is an alphabetic language in which the letters are used to represent sounds. The English writing system represents or codes words at a phonological level. The beginning reader must learn that printed symbols (i.e., letters of the alphabet) represent units of speech at its most basic level, the phoneme (Crowder, 1982). Knowledge that printed symbols represent specific phonemes is not easily acquired by some children.

Persons with adequate phonemic awareness have a number of advantages when learning to read (Wagner & Torgesen, 1987). They are likely to view the alphabetic nature of English as a logical way of representing the language. Learning to read new words involves segmenting the letter string into units that correspond to individual phonemes and then blending the individual sounds together to pronounce the word.

Phonemic awareness is related to later reading ability (Snider, 1997; MacDonald & Cornwall, 1995; Lundberg, Oloffsson, & Wall, 1980). Relationships between phonemic awareness and reading are reciprocal (Barron, 1991; Foorman, 1995). That is, children first develop a simple level and later acquire a more complex understanding of

phonemic awareness during and after reading instruction (Wagner, Torgesen, & Rashotte, 1994). Reading difficulties often are caused by deficits in phonological processes (Stanovich, 1988). Phonological processing refers to an individual's ability to correctly receive, interpret, and use phonological information in oral and written language (Felton & Pepper, 1995; Wagner & Torgesen, 1987).

The temporal bank of the sylvian fissure comprises an area of the human brain key to language processing (Leonard et al., 1993). The asymmetry of the horizontal planum temporale is thought to be associated with phonemic awareness in children under 10 years of age (Leonard et al., 1996). Leftward asymmetry of the horizontal planum was elevated significantly in children under 10 years of age who had phonemic awareness. This cross-sectional study demonstrated that phonemic awareness may be related to one specific brain structure (Leonard et al., 1996). Although studies have linked phonemic awareness to later reading ability and to the planum temporale, no studies of phonemic awareness and its relationship to brain development within young children who have just begun or had no formal training in reading could be located.

This study investigates the asymmetry of the horizontal planum temporale in the temporal bank of the sylvian fissure and its relationships with phonemic awareness, rapid naming, and emergent reading in young children.

CHAPTER 2
REVIEW OF LITERATURE

Phonological Development

Learning to read is a complex process: one most adults take for granted. When learning to read, children first must learn to recognize letters and then pair those letters with sounds in order to decode words. The ability to segment sentences into individual words is a prerequisite skill for reading. Even this apparently simple skill is often acquired gradually during the preschool years. Young children develop the awareness of larger linguistic units, such as words and syllables, before they are aware of smaller linguistic units, like phonemes (Fowler, 1991 as cited in Snider, 1995). Although children are aware of spoken words, they do not segment them into words in the same manner as do adults. When asked to name the number of words in a sentence, young children often will count the number of prepositions or ideas conveyed by a sentence (Sawyer, Dougherty, Shelly, & Spaanenburg, 1990 as cited in Snider, 1995). If presented with the sentence "Hal and Russ went fishing" very young children typically would respond that it has two words (e.g, "Hal went fishing" and "Russ went fishing."). They focus on the number of ideas conveyed by the sentence, not the number of words. After acquiring the ability to segment sentences into prepositions or ideas, children then segment the prepositions into subject and predicate terms. The sentence "Billy ran home" would be said to contain two words, "Billy" and "ran home." Children occasionally make

mistakes when decoding sentences into words before mastering the ability to identify individual words. They may mistake syllables for words and not recognize prepositions as independent words.

Phonological Processing

Phonological processing refers to an individual's ability to correctly receive, interpret, and use phonological information in oral and written language (Felton & Pepper, 1995; Wagner & Torgesen, 1987). Phonological processing skills are necessary to accomplish the decoding of words into their component sounds and thus into recognizable words. Three types of phonological processes are critical for the development of basic reading skills: phonological recoding in lexical access, phonetic recoding to maintain information in working memory, and phonemic awareness (Felton & Pepper, 1995; Wagner & Torgesen, 1987).

Phonological Recoding in Lexical Access

Phonological recoding in lexical access refers to the process of translating a written word into its auditory representation by recoding the written symbols into a sound-based representational system. Assessment of phonological recoding in lexical access typically is conducted with tasks in which individuals decide whether a string of letters represents a real word or nonword, or tasks that require rapid naming of objects, colors, and other kinds of stimuli. Respondents are timed while rapidly naming colors, objects, or other stimuli.

Naming-speed deficits are predictive of word recognition and oral reading ability (Wolfe, 1991; Cornwall, 1992) and are viewed as an indicator of severe reading disabilities (Wagner, Torgesen, & Rashotte, 1999; Wolfe, 1997; Felton, Naylor, & Wood,

1990). In addition to other processes, the rapid naming of colors, numbers, and letters requires efficient and fluid retrieval of phonological information from long-term memory. While reading, children must retrieve phonemes associated with letters. The efficiency with which children are able to retrieve phonological codes associated with individual phonemes influences the degree to which phonological information is useful in decoding printed words. Younger children's rapid naming performance for digits and numbers may be limited by their unfamiliarity with them. Therefore, younger children are asked to name common colors in rapid naming tasks.

A relationship between reading skills and the ability to name colors, objects, letters, and digits rapidly has been well documented (Cronin & Carver, 1998; Denckla, 1972; Denckla & Rudel, 1976; Korhonen, 1995). The ability to rapidly name colors was predictive of reading achievement in kindergarten, and both rapid naming of letters and colors were significant predictors of reading achievement in first grade (Blachman, 1984). However, in older children, rapid naming of digits and letters is more predictive of reading than is rapid naming of colors (Wagner, Torgesen, & Rashotte 1999; Cornwall, 1992). It is possible that weak associations between phonological representations of the letters and numbers result in the difficulty with retrieval. The processes associated with naming letters and digits are likely more dependent on these phonological associations than retrieving an entire word, like a color. Recall, that when naming colors, the child is actually looking at the color, not a series of letters or digits.

Phonetic Recoding to Maintain Information in Working Memory

Phonetic recoding to maintain information in working memory refers to the translation of symbols into their sound-based representational system in a fashion that

enables the sounds to be maintained efficiently in working memory during ongoing processing. Phonetic recoding is thought to be important to the acquisition of beginning reading (Wagner & Torgesen, 1987). The beginning reader must decode a series of visually-presented letters, store the sounds associated with the letters in temporary storage, and blend the contents of the temporary storage to form words. While sounding out 'car,' the reader must decode it into the individual phonemes 'c-a-r' and store it in short term memory long enough to blend the phonemes together to form a word. The ability to code and store the sounds of the letters efficiently allows the beginning reader to devote more of his or her cognitive resources to the more advanced task of blending the sounds to form words and comprehending their meaning.

Phonemic Awareness

Phonemic awareness involves the conscious awareness that sentences are composed of words and that words are composed of phonemes; and the ability to manipulate those individual sounds (Snider, 1995; Snider, 1997; Wood & Terrell, 1998). Speech is represented at the phonetic level by the phone (i.e.; a set of speech sounds found in languages) (Wagner & McBride-Chang, 1996; Wagner & Torgesen, 1987). Midwestern spoken English can be represented by a total of 45 phonemes (16 vowel and 29 consonant) (Denes & Pinson, 1963 as cited in Wagner & Torgesen, 1987). Letters within the alphabet usually are associated with more than one phone. Every spoken word in the English language can be generated by generated by combining these basic sounds (Wagner, Torgesen, & Rashotte, 1994). Of the nearly infinite number of possible sound combinations found within a language, only a small percentage are used, and of those used, they often share common combinations. Knowledge of the phonological structure

of words should assist beginning readers in their attempts to master the alphabetic form of their spoken language. That is, a beginning reader would recognize that 'bat' sounds like 'fat' and, thus, probably shares common letters.

The perceived-sound distinctions (e.g., the sound of the letter t differs in the words ten and stop) are allophones, related phones that are combined into families called phonemes. Phonemes represent differences in speech sounds that signal differences in the meaning of words heard in everyday speech (Wagner & McBride-Chang, 1996). Phonemic awareness can be tested by having persons count the number of sounds in a word, reverse the order of sounds in a word, and combine isolated individual sounds to form a word (Wagner & Torgesen, 1987).

Difficulties with forming precise phonological representations in long-term memory have been proposed as a possible cause of the phonological weaknesses characteristic of dyslexia (Elbro, 1998; Fowler, 1991). Distinctness of phonological representations is referred to as the magnitude of the difference between a representation and its neighbors (Elbro, 1998). The distinctness hypothesis as it relates to reading difficulties proposes that children who have severe difficulties in learning the alphabetic principle in reading possess relatively indistinct phonological representations, or have other difficulties in accessing distinct phonological representations (Elbro, 1998). The distinctness of phonological representations influences the speed and accuracy of different phonological processes.

The distinctness hypothesis suggests that reduced distinctness levels may be a cause of the well-documented phonological processing difficulties in dyslexia. Dyslexic adults were found be specifically impaired in their ability to distinctly pronounce target

words when compared with controls (Elbro, Nielsen, & Petersen, 1994). Children were given several tests of language abilities (i.e., phoneme awareness, syllable awareness, morpheme awareness, phoneme discrimination, verbal short-term memory, picture naming, and articulatory fluency), pre-reading abilities, and cognitive ability in kindergarten (Elbro, Borstrom, & Petersen, 1994). They were tested again at the beginning of second grade. The language measures in kindergarten were significant predictors of possible dyslexia. Non-verbal IQ (i.e., Raven's Progressive Matrices) did not predict later reading problems. The three kindergarten measures found to independently predict dyslexia were letter knowledge (i.e., naming letters), phoneme awareness, and distinctness of phonological representation. These studies suggest that the quality of phonological representations in language may play an important role in the development of phoneme awareness as it later relates to reading.

Phonemic awareness has different levels or components, some of which are more difficult than others to master. Five levels of phonemic awareness have been identified (Adams, 1990; Snider, 1997). The appreciation of sounds in spoken language is the first and easiest level. The ability to rhyme is associated with later reading ability. A 4-year longitudinal study found that the degree of awareness of rhyme and alliteration children acquired before they went to school is associated with their eventual success in learning to read and spell (Bradley & Bryant, 1983). A positive relationship between the detection and production of rhyme and early reading also was found in a longitudinal study (Maclean, Bryant, & Bradley, 1987).

The use of rhyme and alliteration when comparing and contrasting sounds in words is the second level of phonemic awareness. An ability to group words with similar

or dissimilar sounds at the beginning, middle, or end of a word (e.g., shoe and shirt, rat and tap, back and rack) displays this skill. The blending of split syllables (i.e., to identify a word when each syllable is pronounced separately) and splitting complete words comprises the third level of phonemic awareness. The child must be aware that words can be divided into their corresponding phonemes, the child must also be familiar with how the phonemes sound when produced in isolation. Phonemic segmentation, the fourth level, refers to the ability to isolate individual sounds in syllables (e.g., to pronounce each separate phoneme in a word). The ability to manipulate phonemes by adding, moving, or omitting them to make new words (i.e.; remove the 'l' sound from slide to produce 'side') constitutes the fifth and most advanced level of phonemic awareness.

Phoneme manipulation and phoneme segmentation predict beginning reading acquisition. These skills generally are unattainable by children who have received no formal reading instruction which adds support for the importance of reading instruction in the development of phonemic awareness skills (Adams, 1990).

Reading And Its Relationship To Phonological Processing

The cooccurrence of deficits in naming-speed and phonemic awareness has been found in persons with severe reading disabilities (Wagner, Torgesen, & Rashotte, 1999; Wolfe, 1997; Felton, Naylor, & Wood, 1990). Phonemic awareness is necessary for reading and spelling in English because the language is alphabetic (i.e., the letters represent sounds). The meaning of a word is found when the letters are translated into a word used in one's vocabulary through a process called decoding (Wagner & Torgesen, 1987; Snider, 1995). The English writing system uses symbols (i.e., letters) to represent spoken language at its phonological level. The beginning reader must learn that printed

symbols represent units of speech (Crowder, 1982; Snider, 1997). The written word represents the sounds in the word being read or pronounced but with alterations that often reflect a word's meaning, for example 'herd' and 'heard' (Crowder, 1982). The most difficult part of learning to read is learning that printed symbols represent specific phonemes; a person must become aware of the phonological principles in English.

Phonemic awareness develops at about the time children typically are taught to read in school (Wagner & Torgesen, 1997). When learning to read, those with phonemic awareness have a number of advantages over those whose phonemic skills are not well developed (Wagner & Torgesen, 1987). Also, the process of learning to read new words involves segmenting the letter string into corresponding units and blending the phonemes together to pronounce the word. An awareness of phonemes is required before segmenting the letter strings into phoneme-based units and blending the resulting phonemes into words. The process of learning to read also may affect the development of phonological awareness by providing instrumental knowledge of the phonological structure of language, knowledge that complements one's implicit knowledge acquired from speaking and listening.

Longitudinal studies found a predictive relationship between phonemic awareness and later reading ability (Snider, 1997; MacDonald & Cornwall, 1995). Correlations between kindergarteners' performance on phonological awareness tasks and their word-reading skills at the end of first grade typically fall in the 0.4 to 0.6 range (Torgesen, Wagner, & Rashotte, 1994). Phoneme segmentation, the ability to strip the initial consonant sound, and the ability to substitute the initial consonant sound in kindergarten predicted reading achievement (i.e., word analysis and reading comprehension subtests)

at the end of second grade as measured by the California Achievement Test and Iowa Test of Basic Skills (Snider, 1997).

Thirty-two, 6-year-old Finnish children were assessed twice: first on entering first grade for phonemic skills and motivational orientations, and again at the end of first grade for word reading skills. The ability to delete a syllable from a word (0.51), blend sounds (0.50), name the initial sound of a word (0.53), delete the initial sound of a word (0.53), and the combination of the four tasks to form a phonemic awareness score (0.51) was significantly related ($p<.01$) to first-grade word-reading skill (Salonen, Lepola, & Niemi, 1998).

The analytic ability to manipulate phonemes was the strongest determinant of reading and writing among second-grade Swedish students (Lundberg, Olofsson, & Wall, 1980). Two-hundred children were assessed first in kindergarten, again one year later at the end of first grade (n=143), and finally 6 months later at the beginning of second grade. Children who showed no signs of reading ability in kindergarten also were unable to manipulate phonemes. The ability to reverse phonemes strongly predicted reading ability. Thus, reading and spelling achievement of second grade students can be predicted with some accuracy from knowledge of their phonemic awareness skills before formal reading instruction.

An eleven-year study of relationships between phonological awareness and reading and spelling achievement found phonological awareness among Canadian kindergarten children to predict word identification and spelling skills of teenagers. Socioeconomic status (SES) and vocabulary development were controlled in the analysis (MacDonald & Cornwall, 1995). Surprisingly, SES, vocabulary development, word

recognition, and spelling achievement assessed at kindergarten were uncorrelated with reading and spelling achievement 11 years later.

Reading Instruction is important to the development of phonological awareness

Longitudinal evidence suggests that phonological awareness (i.e., a broad awareness of the sound structures in language) and literacy develop as a result of reciprocal influences (Wagner, Torgesen, & Rashotte, 1994). Furthermore, the development of alphabetic awareness and phonological awareness is reciprocal (Wagner et al., 1994; Mc Guinness, Mc Guinness, & Donohue, 1995).

Historically, the nature of the development of phonemic awareness was debated (Barron, 1991; Wagner & Torgesen, 1987; Wood & Terrell, 1998). Recall that phonemic awareness is the knowledge of the phonemic structure of words (Snider, 1997; Wagner & Torgesen, 1987; Wood & Terrell, 1998). A disagreement among scholars centered on whether phonemic awareness arises as a result of reading instruction or is merely part of the natural development of phonological awareness (Wagner & Torgesen, 1987; Wood & Terrell, 1998).

Adams (1990) stated that children's knowledge of phonemes is highly developed before to learning to read. She adds that if it were not, children could not produce nor understand oral language. However, according to Adams, children's knowledge of phonemes is a working knowledge and not at a conscious level. Phonemic awareness becomes conscious only when it is taught specifically and in conjunction with the learning of the alphabetic script. The development of phonemic awareness seems to rely on a child being in a situation in which the skill is required. That situation occurs when

children learn to read (Adams, 1990). She adds that practice and training are more important than age and maturation to the development of phonemic awareness.

Research has been conducted with non-readers to determine the direction of the relationship between the development of phonemic awareness and reading instruction. The relationship between phonological awareness and the acquisition of reading skills was studied in illiterate Portuguese adults who had received no reading instruction (Morais, Cary, Alegria, & Bertelson, 1979). The investigators hypothesized that illiterate people are unable to perform tasks requiring conscious phonetic analysis if the improvement in phonemic awareness observed between the ages 5 and 6 is related to reading instruction. Adult participants were given tasks that involved deleting, adding, and reversing the order of sounds and syllables in words and non-words. Over half of the illiterate participants failed every trial presented. In the phoneme addition trials, participants introduced a new phone at the beginning of each word. The illiterate group read correctly 46% of the words and 19% of the nonwords. In contrast, the reading group read correctly 91% of the words and 71% of the nonwords respectively. In the deletion task, the participants deleted the first sound. The illiterate group was able to correctly delete the sound 26% of the time for words and 19% for non-words. However, the literate group correctly deleted the sound 87% of the time for words and 73% of the time for non-words. These results indicate that phonemic awareness does not arise spontaneously. Learning to read, regardless of age, requires that phonemic awareness manifest itself.

<u>Phonemic awareness is present before reading instruction.</u> Lundberg (1991; 1994) believes the development of phonemic awareness, if solely dependent on reading

instruction, would not exist in preschool, preliterate children. Lundberg reviewed a subset of nonreaders in a previously collected data set (Lundberg et al., 1980). Nine of the 51 children could segment phonemes, and four were able to achieve favorable scores on more complex phoneme-manipulation tasks. In another study, a sample of 387 Scandinavian preschool children correctly completed 75% of the rhyming tasks, 50% of the syllable segmentation tasks, and 9% of the phonemic awareness activities (Lundberg, 1994). Lundberg suggests these statistics offer evidence that, despite the development of phonemic awareness being low in preschoolers, the realization that some children are able to exhibit phonemic ability demonstrates that development of phonemic awareness is not merely a result of reading instruction. However, these studies did not take into account instruction provided by parents or exposure to literature in the home environment.

Pre-reading preschool children who show signs of emergent reading ability demonstrate higher phonemic and phonological awareness skills than their same aged peers (Bowey, 1994). Emergent reading skills include knowledge of letters, reading simple words, reading comprehension (Bowey, 1994; Raz & Bryant, 1990). In contrast, phonemic processing skills involve the ability to correctly receive, interpret, and use phonological information (Felton & Pepper, 1995). Terrell and Wood (1998) found that preschool children who received no explicit training in reading exhibit both simple and complex phonemic awareness. Thirty 3- and 4-year-old native English-speakers with no formal reading instruction were given phonological tasks. The tasks included sentence segmentation, syllable/onset-rime/phoneme segmentation, syllable/onset-rime/phoneme blending, rhyme detection, alliteration tasks, phoneme deletion, and letter-sound knowledge. Correct responses on measures of simple phonemic awareness (e.g., letter-

sound knowledge) and alliteration detection (e.g., the ability to detect common initial sounds across words) were 49% and 48% respectively. The children obtained an average of 25% accuracy on the phoneme deletion task (e.g., a test of complex phonemic awareness). Lower levels of attainment were exhibited on the phoneme segmentation task (e.g., splitting words into their phoneme units 13%; phoneme blending 8%). This evidence supports the contention that simple and complex phonemic awareness may emerge as a part of the natural development of phonological awareness and without specific reading instruction.

Reading instruction and phonemic awareness are reciprocal Others propose reciprocal relationships between phonemic awareness and reading (Barron, 1991 & Foorman, 1995). Children become sensitive to syllables and subsyllabic phonological units before they learn to read but the alphabetic reading experience itself may be necessary to trigger understanding of phonemic units of sound (Bowey, 1994). The reciprocal relationship between reading and phonemic awareness may reflect the fact that alphabetic writing systems symbolize a linear phonemic transcription of spoken language. This relationship creates a paradox: understanding an alphabetic writing system appears to presuppose sensitivity to phonemes as units of spoken language, but understanding an alphabetic writing system itself appears to stimulate this insight (Bowey, 1994).

Perfetti, Beck, Bell, and Hughes (1987) found that, although having some phonemic knowledge is important for beginning reading, the relationship between phonemic knowledge and learning to read is reciprocal. Barron (1991) suggests that phonological awareness may emerge only after specific instruction in literacy. The relationship may be bi-directional. A longitudinal study (Wagner, Torgesen, &

Rashotte,1994) reported that causal relationships between the development of phonological processing abilities and the acquisition of reading skills are bi-directional. Children were assessed annually first in kindergarten and finally in the second grade on the five previously discussed basic levels of phonological processing (i.e., knowledge of rhyme, comparing and contrasting sounds in words, blending split syllables, phonemic segmentation, and phonemic manipulation). There was an interaction between the level of phonological processing ability and grade, indicating that phonological processing abilities did not develop at a uniform rate. Their results support the existence of multiple reading related phonological processing abilities. The researchers believe phonological awareness is not a unitary homogenous skill but is one that is heterogeneous, with different forms of phonological awareness being associated with different aspects of literacy.

Further evidence of a schooling effect was presented by Bentin, Hammer, and Cahan (1992). They found kindergarten children display some natural development in their phonological awareness. However, once they attend school their rate of phonemic awareness increases significantly.

Reading Skills and Their Relationship to Intelligence and Socioeconomic Status

Intellectual ability is the single best predictor of scholastic achievement (Sattler, 1992; Herrnstein & Murray, 1994). Furthermore, intelligence has been found to be highly predictive of reading ability (Carver, 1990; Cornwall, 1992). The Raven Progressive Matrices and the National Reading Standards (NRS) were used to assess intelligence and its relationship to reading achievement in 486 second- to twelfth-grade students from a rural midwestern school system (Carver, 1990). The Raven was chosen because it does

not readily tap a recognized subskill of reading but instead measures abstract reasoning ability or *g*. The correlation between the Raven and the NRS ranged from 0.36 to 0.68 in each of the grades and indicates a strong relationship between intellectual and reading ability.

In a separate study, the verbal comprehension factor of the Wechsler Intelligence Scale for Children-Revised (WISC-R) was found to be the best predictor of reading phonetically regular nonsense words, reading comprehension, spelling, prose passage speed, reading accuracy scores even when controlling for age and socioeconomic status among children with reading and spelling disabilities (Cornwall, 1992).

Socioeconomic status (SES) reflects an individual or family's financial resources, occupation, and educational background. SES is strongly linked to intellectual ability and achievement, including reading skills. The correlation between a family's SES and children's intelligence averages about .33 (Sattler, 1992; Andersson, Sommerfelt, Sonnander, & Ahlsten, 1996). Among five year-olds, family income correlated more highly with intelligence than did maternal education, ethnicity, and female headship of the household (Duncan, Brooks-Gunn, & Klebanov, 1994).

Differences in the way children realize and use language within the same context is related, in part, to the language environment in which they live (Bernstein, 1970). Children who differ in their access to speech systems or codes may acquire quite different social and intellectual orientations and procedures despite a common developmental potential. Bernstein (1970) proposes two fundamental types of linguistic codes, elaborated and restricted. In elaborated codes, communication is individualized and the message is specific to a particular situation, topic, or person. Elaborated codes are more

precise, differentiated, and permit an expression of a wider and more complex range of thought. In restricted codes, language is stereotyped, limited, and condensed, lacking in specificity and the exactness needed for precise conceptualization, differentiation, and discrimination. Restricted codes are found predominantly in the social and family structures of lower-class groups. While restricted codes may promote cohesiveness and reduce tensions within a group, they do not promote cognitive elaboration. Upper socioeconomic groups use both restricted and elaborated codes, depending on the context.

Relationships between SES and communication style based on Bernstein's restricted (i.e., status-oriented) or elaborated (i.e., elaborated and person-oriented) forms were studied in 163 non-working African American mothers and their 4-year-old children (Hess & Shipman, 1965; Olim, Hess, & Shipman, 1967). The researchers postulated that the structure of the social system and the structure of the family shape communication and language. Language shapes thought and the cognitive styles of problem-solving by structuring and conditioning what and how a child learns and by setting limits within which future learning may take place.

The researchers elaborated on the categories proposed by Bernstein and reported that a mother may use three basic approaches to control and discipline her child: inhibitory techniques, input-control techniques, or internalizing techniques. Inhibitory techniques keep a response from recurring or prevent the child from considering alternative solutions. These inhibitory responses make the child aware of external sanctions on his or her behavior without weighing alternatives. Input-control techniques restrict information and alternatives open to a child. Internalizing techniques regulate behavior by appeals to logical considerations or objective consequences (i.e., If you pull

the dog's ears, he will get angry and may bite you). The internalizing approach makes the child aware that choices are open to him and encourages him to choose wisely and promotes internal cognitive control.

The researchers divided the women into three groups based on the method used by the women to control their child's behavior. The status-normative-oriented mother presented rules in an assigned manner where the only possibility for the child was to comply (i.e., an uncritical acceptance of the social status). The personal-subjective techniques took into account the qualities and reactions of the persons involved. Cognitive-rational techniques appealed to rational principles and the objective consequences of various alternatives of action. The latter two methods rely heavily on internalizing techniques for behavioral regulation.

The mothers were categorized into four social status levels: college-educated professional, executive, and managerial occupations; skilled blue-collar occupational levels, with no more than a high school education; unskilled or semiskilled occupational levels, with predominantly elementary-school education; and unskilled or semiskilled occupations with absent fathers and the family's support coming from public assistance.

These mothers were interviewed in their homes and brought to the university for testing. The mothers' responses to interview questions were recorded and scored. The mother was taught three simple tasks by the staff member and was then asked to teach these tasks to their child. The three tasks were: sort or group a number of plastic toys by color and function; sort eight blocks by two characteristics simultaneously; teach the child to copy five designs on an "Etch-a-Sketch" toy.

The children of mothers who used status-normative control techniques generally performed at a lower cognitive level than children of mothers showing a preference for person-centered or cognitive-rational techniques. The children were assessed with the Stanford-Binet (Form L-M), the conceptual style dimensions from the Sigel Conceptual Sorting Task for Children, and verbal and physical scores from a concept-attainment block-sorting task. The scores of mothers' with status-normative orientations were negatively correlated with all measures of the child's ability and positively correlated with the child's inability to explain the rationale behind his or her decisions for classification on the Sigel task.

The mothers' language styles were significantly related to her child's performance on the various cognitive measures. The measures of language style included: mean sentence length, mean pre-verb length of sentence, verb elaboration, syntactic elaboration, and abstraction. High maternal language elaboration was associated with stronger cognitive performance. All language elaboration measures were negatively correlated with the status-orientation but positively correlated to the personal-subjective and cognitive-rational orientations. The language measures were negatively related to the mothers' use of imperatives (i.e., must do this) as opposed to mothers who used instructions for guiding her child's behavior.

Mothers oriented toward status-normative control using the imperative and restricted language codes tended to be from among the lower SES groups. Mothers oriented to personal-subjective or cognitive-rational control, who gave instructions, and elaborated language styles tended to be from the middle-class group. The researchers

concluded that the nature of the language used by mothers has a significant impact on the development of her child's cognitive and language skills.

A longitudinal study of 121 children ages three through eight found home environment, as measured by four subscales (i.e., learning materials, stimulation of communicative competence, physical environment, and academic stimulation) of the Home Observation for Measurement of the Environment (Caldwell & Bradley, 1978), and SES to predict children's intelligence most highly (Molfese, DiLalla, & Bunce, 1997). Birth risk factors (i.e., birth complications that resulted in the neonate being placed in a neonatal intensive care nursery but which, in themselves, were not likely to produce permanent cognitive impairments) did not predict intelligence at any age after controlling for home environment and SES.

Kindergarten children from middle SES families were found to have more highly developed phonological structure than children from low SES families (Wallach, Wallach, Dozier, & Kaplan, 1977). Group differences on auditory discrimination of phonemes were not significant. However, when given tasks of phonemic analysis (choosing a picture whose name starts with the phoneme at issue and indicating whether a word starts with the phoneme at issue), middle-class students outperformed low SES children ($p < .001$).

Socioeconomic status was found to predict reading phonetically regular nonsense words and the ability to identify words (Cornwall, 1992). Middle-class preschoolers displayed more advanced pre-reading skills (e.g., print production, print decoding, literacy, knowledge of environmental print, phonemic awareness, and story understanding) than preschoolers in lower socioeconomic groups despite both groups

attending "high quality" nursery schools and kindergarten classes (Dickinson & Snow, 1987). African Americans have been found to possess nonstandard phonological, syntactic, and morphological forms of language (Ratusnkik & Koenigsknecht, 1975). Among African American preschool children, those from lower SES homes used more nonstandard phonological and grammatical components of language than did those from middle SES homes (Ratusnkik & Koenigsknecht, 1975).

Strong links between intellectual ability, academic achievement, and socioeconomic status have been well established in the literature. Unless intellectual ability is controlled, the results from studies examining the influence of SES may be misleading as such data may reflect differences in intelligence. Therefore, the effects of these influences (i.e., IQ, socioeconomic status, gender, and handedness) were controlled in the present study.

Although current trends in the literature contend that relationships between learning to read and phonological processes are bi-directional, none has investigated the possibility of the influence of a specific biological correlate in the brain for both phonemic awareness and reading acquisition. Research on relationships between phonemic awareness and cortical structures in the brains of very young children was not located.

Brain Development

Importance of Early Stimulation

A number of critical or sensitive periods exist during the first few years of life during which time the brain demands certain types of input in order to create or stabilize long-lasting structures. Long-term effects of inadequate nurturing during infancy can be

devastating. The term hospitalism was coined by Spitz (1945) to describe the physical condition due to long periods of confinement in a hospital, particularly the negative effect of institutional care during the first months of life.

Infants who lived in a sterile environment with no toys and bleak lighting fared much worse than infants reared in a penal institution nursery where they continued to have contact with their mothers. Infants in the sterile environment were handled by nurses and removed from their cribs only at feeding time. One head nurse and five assistant nurses cared for 45 babies. In the penal institution nursery, most infants were fed, nursed, and cared for by their own mothers who were supervised by a head nurse and three assistants. A follow-up study conducted two years later and supervised by Spitz (1946) found children who continued to remain in the sterile environment fared poorly in every area of development. Thirty-seven percent had died. Spitz (1946) reported that the damage inflicted on the infants by their being deprived of maternal care, stimulation, and love as well as by their being completely isolated, was irreparable. The developmental imbalance caused by the unfavorable environmental conditions during the child's first year produces psychosomatic damage that cannot be repaired by any known interventions (Spitz, 1946).

Neuroanatomical effects of early sensory deprivation have been studied in laboratory animals. The development of the brain's visual center connections has been studied in depth in laboratory animals. Deprivation of form and light during the first three months of life in kittens led to marked abnormalities, including behavioral blindness, morphological changes in the lateral geniculate body, and the disruption of innately-determined cortical connections (Wiesel & Hubel, 1965). Additionally, a

kitten's capacity to recover from the effects of the early visual deprivation behaviorally, morphologically, or in terms of single cell cortical physiology was severely limited, even when recovery periods extended over more than one year.

Rats who were reared in environments rich in stimuli were found to have heavier cerebral cortexes when compared to their littermates raised in an impoverished condition (Rosenzweig, Krech, Bennett, & Diamond, 1962).

Handedness

The effects of handedness also can impact neuroanatomical development. Handedness (Harris & Carlson, 1988) refers to the arms and hands being asymmetrical in use and function so as to reliably favor one hand over the other across a range of skilful acts (e.g., writing, throwing, using tools). The dominant right-hand preference among the majority of humans is believed to extend far back in the evolutionary cycle (Annett, 1985). Evidence from ancient tools, weapons, and art suggests that the preference for using the right hand has existed since the stone-age (Annett, 1985). Historical artifacts and records suggest left-handers always were in the minority, ranging from only 2% to 15%-- 20% of the population (Harris & Carlson, 1988). At present, approximately 10% of the population is left-handed, a proportion estimated to have remained stable for the past 5,000 years (Satz, Soper, & Orsini, 1988).

Although right-handed persons comprise the majority, left-handedness is disproportionately prevalent among children with reading disabilities (Kinsbourne, 1988). Left-handedness is more frequent in men, and males comprise the majority of those diagnosed with autism, dyslexia, stuttering and other developmental disorders (Geschwind & Galaburda, 1985). The lateralization of language to the left hemisphere

almost always occurs in right-handed individuals. However, the speech pattern in left-handed individuals is less certain (Harris & Carlson, 1988). The left hemisphere is lateralized for language in about 60% to 70% of left-handers, with the remaining 30% to 40% being lateralized rightward or bilaterally (Harris & Carlson, 1988).

Human Brain Volume

The human brain reaches its maximum size in the late teens (Caviness, Kennedy, Bates, and Makris, 1997; Dekaban & Sadowsky, 1978). The increase in brain volume does not occur in a linear fashion. The rate of growth is fastest during fetal and early postnatal life. The brain weighs approximately 100 g at 20 weeks gestation and 400 g at birth. At 18 months, the brain is 800 g, a figure 60% of its projected weight of 1100 g at age 3; at age 3 years, this weight is 80% of its projected adult size (Lemire, Loeser, Leech, & Alvord, 1975). The brain is approximately 95% of its adult size by age five (Dekaban, 1977; Dekaban & Sadowsky, 1978). At age five, the rate of brain growth slows (Dekaban & Sadowsky, 1978). The brain prunes its weakest and unutilized synapses throughout its development.

Male and Female Brain Differences

Brain weight is greater in males than females at all ages (Dekaban & Sadowsky, 1978). The brain volume of female children is approximately 93% of male children of the same age (Caviness et al., 1997). Absolute cerebral volume is approximately 10% larger in boys than girls but the relative proportion of tissue and fluid volumes is similar (Reiss, Abrams, Singer, Ross, Denckla, 1996). This difference in total cerebrum size between male and female children was significant after controlling for height and weight (Giedd, 1997; Geidd et al., 1996). This difference in volume of the whole brain is

uniformly scaled among the major brain regions: cerebrum, cerebellum, and the brain stem (Caviness et al., 1997).

Some brain regions have been found to not follow the aforementioned proportional differences between genders. Gender differences in the temporale lobe size were not significant when adjusted for total cerebral volume (Giedd et al., 1996; Giedd et al., 1997). The caudate, hippocampus, and pallidium areas are similar in size in both genders. Intelligence increases with larger volume to a point, reaches an asymptote, and seemingly decreases with the largest cerebral volumes (Reiss et al., 1996).

A post-mortem study of 10 males and 11 females aged 46 to 92 found the volume in language-associated cortical regions to be larger in females than males (Harasty, Double, Halliday, Kril, & McRitchie, 1997). Compared to males, females had significantly smaller brains but similar sized language-associated brain regions. The proportion of the total brain occupied by the left and right homologue of Broca's area was 20% larger in females than males. The left and right superior temporal gyri occupied 18% more of the total brain in females than in males. The planum temporale, the posterior language-associated subsection of the superior temporal gyrus, was 30% larger in females. A gender-associated difference in volume fraction was not observed in either Heschl's gyrus, which is associated with hearing, or the anterior superior temporal gyrus. The authors (Harasty, Double, Halliday, Kril, & McRitchie, 1997) concluded the planum temporale accounts for most of the increased volume fraction of the superior temporal gyrus in the female brain. Compared to males of similar age, the left planum temporale in females between ages 3 and 14 is larger than the right (Preis, Jancke, Schmitz-Hillebrecht, & Steinmetz, 1999).

Gender is associated with an increased total brain volume in males and with larger planum temporale volumes in females. Due to the literature suggesting gender influences total brain volume and the size of the planum temporale, gender was controlled in the analyses.

The Temporal Lobe

The temporal lobes, the most lateral and ventral aspects of the cerebral cortex, lie between the lateral sulcus and the collateral sulcus (Haines & Mihailoff, 1997).

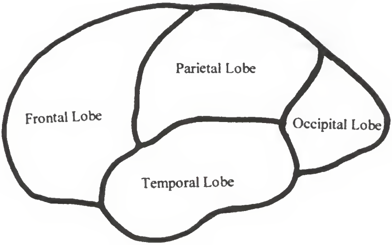

Figure 1. The four hemispheres of the cerebral cortex.

The gyri that form the temporal lobe begin at the sylvian fissure and consist of the superior temporal gyrus, medial temporal gyrus, and the inferior temporal gyrus. The occipitotemporal gyri, a broad area of cortex that extends from the temporal pole to the occipital pole, is on the ventral side. The superior temporal sulcus terminates in the cortex and forms the angular gyrus of the inferior parietal lobe.

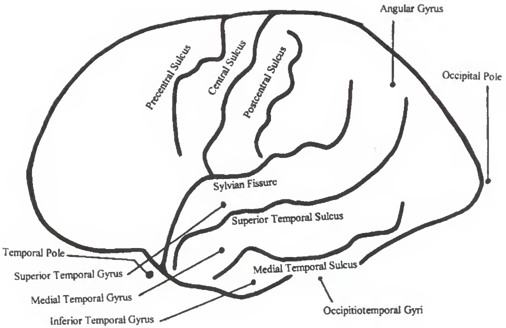

Figure 2. Major anatomical landmarks in the human brain.

The transverse temporal gyri of Heschl, or Heschl's gyrus, is found on the upper edge of the temporal lobe and extends into the lateral fissure (i.e., the sylvian fissure). The primary auditory cortex is located in Heschl's gyrus. Heschl's gyrus is deep within the lateral sylvian fissure, covered by parts of the frontal and parietal opercula, and continues into the superior temporal gyrus. The smooth area caudal to Heschl's gyrus is the planum temporale, that usually is larger in the left than the right hemisphere.

The gestational development of the temporal lobe was studied in 207 fetal brains (Dooling, Chi, & Gilles,1983). The sample included approximately equal numbers of male and female brains and excluded brains with obvious malformations, large

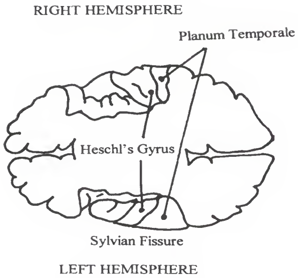

Figure 3. Axial view of heschl's gyrus and the planum temporale.

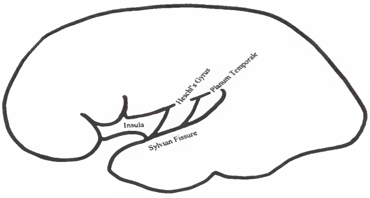

Figure 4. Cutaway view with parietal opercula opened to reveal Heschl's gyrus and the planum temporale.

hemorrhagic or necrotic areas, or architectural distortion. The gestational age of a structure's appearance was determined when 25 to 50% of the brains in a particular age group contained the structure.

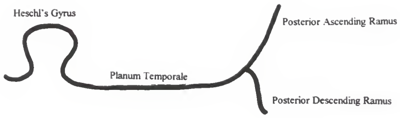

Figure 5. Schematic of Heschl's gyrus, the planum temporale, and the posterior ascending ramus and posterior descending ramus.

The lateral surface of the temporal lobe remains smooth until 23 weeks at which time the superior temporal gyrus is delimited to in the middle posterior part superiorly. The superior temporal sulcus is generally recognizable earlier on the right side than on the left. At 26 weeks gestation, the middle temporal sulcus delineates the middle temporal gyrus. Between 34 and 35 weeks, the secondary sulcation and gyration of the superior and middle temporal gyri occur. Right-left asymmetry of Heschl's gyrus also occurs during this period (Dooling, Chi, & Gilles,1983). Heschl's gyrus is the gyrus medial to a distinct furrow in the medial surface of the superior temporal gyrus of the sylvian fissure. The furrow extends posteriorly and medially until its terminal junction with the posterior end of the insula. This gyrus appears at about 31 weeks and is asymmetric. The Heschl's gyrus typically is recognized one to two weeks earlier on the right side. However, the gyrus appears at about the same time in both hemispheres in approximately one-third of the fetuses. The gyrus extends more rostrally in the right and more caudally in the left. Differences also appear in angulation of the gyri. The left Heschl's gyrus is shorter in height and runs a more obtuse angle to the anterior-posterior axis of the brain. Because

the sylvian fissure is longer in its anterior-posterior extent in the left hemisphere, the planum temporale (e.g., the superior temporal surface area posterior to Heschl's gyrus) also is more extensive in the left hemisphere. The difference in the length of the planum temporale becomes more striking as the fetus matures. In addition, after 36 weeks gestation, secondary transverse temporal gyri appear. In 54% of the brains examined, two Heschl's gyri appear in the right and one in the left hemisphere. The findings were reversed in 18% (i.e.; there were two Heschl's gyri on the left and one on the right). The remaining 28% had an equal number of gyri on both sides. No gender differences in the number of Heschl's gyri or the area of the planum temporale were observed.

Structures Related to Phonemic Awareness

Functional magnetic resonance imaging (fMRI) has been used to determine the areas of cortical activation used to actively and passively listen to words and tone sequences. A goal of this research was to determine whether these activation responses represent processing at auditory or linguistic levels (Binder, Frost, Hammeke, Rao, & Cox, 1996). Passive stimulation with words or tones resulted in widespread activation of the superior temporal gyrus including the planum temporale. Thus, the superior temporal gyrus is engaged actively in auditory processing of words and tones. Four areas were activated more by the word than tone tasks during active listening: the superior temporal gyrus (the sulcus that has a role in multimodal integration of sensory information and middle temporal gyrus), posterior inferior temporal gyrus, angular gyrus, and lateral frontal lobe. No change associated with words was located in the planum temporale or planum parietal in either the active or passive conditions. One possible explanation for

this lack of activation may be that the words presented were not novel and required less blood flow to process than would novel words.

The networks associated with auditory processing of language were studied using four stimulus types and fMRI (Friederici, Meyer, & von Cramon, 2000). Participants were presented with normal speech (i.e., function and content words), syntactic speech (i.e., function words and pseudowords), and two word-list conditions (i.e., function words and pseudo words). The presentation of all four stimuli types stimulated Heschl's gyrus bilaterally, the left and right planum temporale, and lateral segments of the midportion of the temporal gyrus. A main effect for hemisphere was found in the posterior portion of the superior temporal gyrus (i.e., the planum temporale and Heschl's gyrus) indicating the dominance of the left hemisphere in auditory language comprehension. Furthermore, the sentence tasks elicited more activation than the word list condition in the posterior portion of the superior temporal gyrus. The anterior portion of the superior temporal gyrus (i.e., planum polare) was activated bilaterally in both sentence conditions. The frontal operculum was activated bilaterally in the syntactic speech condition. Minimal activation was exhibited during the normal speech condition. The researchers concluded that the frontal areas are involved actively only when the brain is presented with syntactic information in unusual circumstances, which is consistent with the findings of the Binder et al. (1996) study.

Diffusion tensor magnetic resonance imaging was used to study the microstructural integrity of white matter in adults with poor and normal reading ability (Klingberg, Hedehus, Temple, Salz, Gabrieli, Moseley, & Poldrack, 2000). Diffusion tensor imaging (DTI) allows measurement of anisotropy. Increased myelination is

associated with greater anisotropy. Poor readers showed significantly lower anisotropy in the white matter of the temporo-parietal region. A significant correlation between Word Identification and Word Attack scores and a mean anisotropy within the left temporo-parietal volumes of interest (VOI) was found. The researchers concluded that white matter underlying the left temporo-parietal cortex plays a critical role in reading ability.

Brain structures associated with auditory processing are discussed by Leonard, Voeller, Lombardino, Morris, Hynd, Alexander, Anderson, Garofalakis, Honeyman, Mao, Agee, and Staab (1993):

> The cortical structures devoted to auditory processing are found in the temporal bank of the sylvian fissure. Heschl's gyrus receives the ascending auditory projections from the medial geniculate and relays them to the secondary auditory cortex of the planum temporale and superior temporal gyrus. This is a site where auditory phonemes could be mapped into visual graphemes relayed from parieto-occipital cortex (p. 461).

Language dysfunction occurs almost exclusively when lesions are on the left side. This puzzled scientists for many years as there are no obvious anatomical differences and very few physical asymmetries between the two hemispheres (Annett, 1985). However, the planum temporale, an area associated with auditory processing, was found to be asymmetrical between hemispheres. The planum temporale is located in the superior inner margin of the temporal lobe (Annett, 1985). The area of the left planum temporale that incorporates the auditory association cortex and is central to language comprehension typically is larger than in the right planum temporale (Best, 1988). The left planum temporale was found to be longer in 65 out of 100 post-mortem brains (Geschwind &

Levitsky,1968). The planum generally was one-third larger on the left than on the right side. However, the planum was longer on the right side in 11 of the 100 brains, and both hemispheres were the same length in 24 brains.

Leftward asymmetry of the planum temporale was found in individuals whose language functions are lateralized to the left hemisphere (Foundas, Leonard, Gilmore, Fennell, & Heilman, 1994). Twelve participants underwent selective right- and left-hemispheric anesthesia (Wada testing) and a magnetic resonance imaging (MRI) scan. The planum temporale was longer on the left in all right-handed persons. In addition, language ability of the 11 right-handed persons was based in the left hemisphere as demonstrated by the Wada procedure. The one left-hander had a rightward asymmetry of the planum temporale and had language lateralized to the right hemisphere as determined by the Wada procedure.

The asymmetry of the perisylvian areas was measured in a group of male children with language impairments (Plante, Swisher, Vance, & Rapcsak, 1991). The perisylvian area as measured in the study contains portions of the frontal and parietal operculae, superior temporal gyrus, and the planum temporale. Six out of eight (75%) of the language impaired boys had symmetry or rightward asymmetry of the perisylvian area. This left to right ratio was significantly different from non-language impaired controls. The authors concluded that atypical perisylvian configuration may be a neuroanatomical marker common to a range of disorders that include inadequate language skills.

Asymmetry in the horizontal planum temporale contributed significantly to the prediction of phonemic awareness (Leonard, Lombardino, Mercado, Browd, Breier, & Agee, 1996). Forty normal children between the ages of 5 and 12 were recruited from the

community to participate. The children were given an MRI and their brain structures were measured using a specialized computer program. Leftward asymmetry of horizontal planum was elevated in children under age 10 who had well-developed phonemic awareness. Horizontal asymmetry of the planum predicted the ability to manipulate phonemes independent of age, as measured by the Lindamood Auditory Conceptualization Test (LAC). The sizes of the horizontal and vertical planum, when combined, were equivalent in all three age groups. Asymmetry of the total planum was elevated in children ages 10 to 12. The absence of a relationship between improvements in phonemic awareness and changes in the vertical planum between ages 5 and 12 provides support for the hypothesis that only the horizontal bank of the planum is related to language skill.

Furthermore, a cross-sectional study of 61 normal right-handed children between ages 3 and 14 found the length of the planum and parietal asymmetry to be unrelated to age (Preis, Jancke, Schmitz-Hillebrecht, & Steinmetz, 1999). In this study MRI data showed no change in the planum temporale or planum parietal asymmetry with increasing age or brain volume. The authors concluded that the lack of evidence for age-related changes in human planum temporale asymmetry adds support for the development of the planum temporale following its evolutionary course that precedes and prepares it for the development of language.

Attempts to combine phonemes into words and to select entire word-forms are disrupted when the posterior persylvian sector is damaged (Damasio & Damasio, 1992). Persons with posterior persylvian damage may be unable to express certain words or form them properly (e.g., they may say loliphant for elephant). They also may substitute a

pronoun or general word for a more specific and descriptive one (e.g. people for woman) or use a word semantically related to the idea they intend to express (e.g. headman for president). Systems associated with the posterior persylvian sector are believed to store the auditory and kinesthetic records of phonemes and the phoneme sequences that constitute words.

Although studies have linked phonemic awareness to later reading ability and to the planum temporale, studies that focused solely on relationships between phonemic awareness and the planum temporale in the brain prior to or during the beginning stages of formal reading instruction could not be located. As previously noted, phonemic awareness and reading acquisition may be reciprocal in their development (Adams, 1990; Barron, 1991; Foorman, 1995; Perfetti, Beck, & Hughes, 1987). Phonemic awareness is observed in young children before they receive any formal reading instruction while more advanced levels of phonological and phonemic awareness are observed in children with emergent reading skills than those with lower skill levels (Bowey, 1994). Based on previous research (Leonard et al., 1996), leftward planar asymmetry is expected to be more highly developed in children who display more advanced levels of phonemic awareness and emergent reading than children who display lower development in these two skills. This study proposes to investigate these relationships in young readers.

Young children eventually may be screened for neurobiological indicators indicative of reading disorders prior to their manifestation. If a predisposition for a reading disorder is recognized anatomically, children could receive intensive primary intervention that reduces the emerging reading disorders. Specific remediation

techniques might be developed and used, based on the location of the neurobiological indicator.

Based on the aforementioned evidence, children between the ages of 5 and 6 who receive little or no training in reading may be expected to display a basic level of phonemic awareness. A schooling effect has been reported (Bentin et al., 1992) wherein children's phonemic ability increased above their estimated developmental levels within a brief period of time after beginning reading training. Evidence that pre-literate preschoolers possess some simple and complex phonological and phonemic awareness skills (Lundberg, 1994) indicates that the cortical anatomy associated with these skills is likely to be developed already or is forming before formal reading instruction. Traditionally, children were thought to begin developing phonemic awareness between ages 5 and 6 along with the beginning of formal reading instruction in schools.

Taking the aforementioned evidence into consideration, the brain regions associated with these skills are expected to be at a beginning stage of development, ready and waiting for reading instruction. Based on this assumption, 5 and 6 year-old children should display varying degrees of leftward asymmetry of the horizontal planum temporale. The degree of asymmetry will be positively related to the level of phonemic awareness. A finding of varying degrees of leftward asymmetry would lend support to the bi-directional hypothesis that phonemic awareness and reading development are reciprocal. Further support for the bi-directional hypothesis would be provided if those students possessing elevated emergent reading skills and strong rapid naming skills possess leftward asymmetry of the horizontal planum temporale.

The goal of this research is to yield further insight into the biological influences on learning to read.

Research Questions for Investigation

Research Question 1

The area of the planum temporale typically is larger in the left hemisphere than in the right hemisphere (Best, 1988; Geschwind & Levitsky, 1968). In contrast, children with language impairments demonstrate symmetry or rightward asymmetry of the perisylvian area, one that includes the planum temporale (Plante, et al., 1991). Leftward asymmetry of the horizontal planum temporale contributes significantly to the prediction of phonemic awareness (Leonard et al., 1996). Thus, the following research question will be investigated: Is the leftward asymmetry of the horizontal planum temporale positively with phonemic awareness skills in young children?

Evidence relevant to Research Question 1

Hypothesis testing associated with research question 1 would be supported leftward horizontal planar asymmetry is associated positively with the three measures of phonemic awareness. Research question 1 would not be supported if there is no relationship found between the three phonemic awareness hypotheses and the horizontal planum temporale, or the relationship is negative.

Research Question 2

As previously mentioned, the area of the planum temporale typically is larger in the left than the right hemisphere (Best, 1988; Geschwind & Levitsky, 1968). In contrast, children with language impairments demonstrate symmetry or rightward asymmetry of the perisylvian area that includes the planum temporale, (Plante, et al., 1991). Leftward

asymmetry of the horizontal planum temporale contributes significantly to the prediction of phonemic awareness (Leonard et al., 1996). Phonemic awareness is predictive of later reading ability (Lundberg et al., 1980; MacDonald & Cornwall, 1995; Salonen et al., 1998; Snider, 1997; Torgesen et al., 1994). The relationship between reading instruction and phonemic awareness is bi-directional (Barron, 1991; Bentin et al., 1992; Foorman, 1995; Perfetti et al., 1987; Wagner et al., 1997). Studies focusing on relationships between leftward asymmetry of the horizontal planum temporale and reading achievement could not be located in the literature. Because of the association between phonemic awareness and later reading ability, the following research question was created: Is leftward asymmetry of the horizontal planum temporale associated positively with emergent reading skills in young children?

Evidence relevant to Research Question 2

Hypothesis testing associated with research question 2 would be supported if leftward horizontal planar asymmetry is related positively with the four measures of emergent reading skills. Research question 2 would not be supported if no relationship or a negative relationship is found between leftward horizontal planar asymmetry and the four subhypotheses.

Research Question 3

As previously noted, the area of the planum temporale typically is larger in the left than the right hemisphere (Best, 1988; Geschwind & Levitsky, 1968). In contrast, children with language impairments demonstrate symmetry or rightward asymmetry of the perisylvian area which includes the planum temporale, (Plante, et al., 1991). Phonological recoding in lexical access (i.e., the process of translating a written word into

its auditory referent by recoding the written symbols into a sound-based representational system) is one of the three previously mentioned types of phonological processing (i.e., phonological recoding in lexical access, phonetic recoding to maintain information in working memory, and phonemic awareness).

The rapid naming of colors, numbers, and letters requires efficient and fluid retrieval of phonological information from long-term memory, and is a measure of phonological recoding in lexical access. The efficiency with which children are able to retrieve phonological codes associated with individual phonemes influences the degree to which phonological information is available when decoding printed words. The cooccurrence of deficits in naming-speed and phonemic awareness has been found in persons with severe reading disabilities (Wagner et al., 1999). Leftward asymmetry of the horizontal planum temporale contributes to the prediction of phonemic awareness (Leonard et al., 1996), one area of phonological processing. Information regarding relationships between the horizontal planum temporale and naming-speed was not located in the literature.

The following research question will be investigated: Is the leftward asymmetry of the horizontal planum temporale related positively with phonological recoding in lexical access as measured by the rapid naming tasks?

Evidence relevant to Research Question 3

Hypothesis testing associated with research question 3 will be supported if leftward horizontal planar asymmetry correlates with the three rapid naming hypotheses measuring phonological recoding in lexical access. Research question 3 will not be supported if the relationship between leftward planar asymmetry and the three rapid

naming hypotheses measuring phonological recoding in lexical access is not significant or is negative.

CHAPTER 3
METHOD

Participants

The participants were 58 normal 5- to 7-year-old children (5.1 to 7.2 years) who had not yet entered the first grade. This age range was chosen because of the following five conditions. Five year-olds are able to lie still without anesthesia. This age is the first stage for the acquisition of metalinguistic skills (Adams, 1990). Developmental changes in the brain are likely between ages five and seven (Leonard, Lombardino, Mercado, Browd, Breier, Agee, 1996).

Prior studies that focus on very young children, the development of phonemic awareness, and its relationship to brain development could not be located. Dramatic improvement in some language skills occurs within this age range (Adams, 1990).

The children were balanced by gender. Participants were recruited from the community in Alachua County, Florida via the University of Florida Laboratory School, P.K. Yonge, the public schools, advertisements in the local newspaper, and local church groups. An attempt was made to draw participants from racially and economically diverse population. Parents provided information on race and socioeconomic status. Children from varying races and socioeconomic backgrounds were recruited. The children and their parents signed informed consent forms after the purpose and risks of the study were explained. These children were screened for head injury, language disability, a history of family psychiatric illness, hearing, and intelligence prior to being

included in the study. The use of normal participants historically was somewhat unusual in MRI studies but is becoming more common. Most earlier MRI studies used scans of patients who were screened to aid in clinical diagnosis of a disorder that was subsequently found to be not present.

Instrumentation

Test Battery

All tests, except where explicitly stated, were administered by trained graduate research assistants in speech pathology or school psychology.

Handedness

Tests of handedness were administered on the day the child was scanned by trained undergraduate research assistants. The children were asked to write or draw, and their writing hand was recorded. A performance battery modified from the Edinburgh battery (Oldfield, 1971) was used to measure hand preference, and the peg-moving test was be used to measure hand skill. The handedness questionnaire was turned into a performance inventory because asking children about their hand preference may not accurately reflect their behavior. Performance with an actual object was assessed. For each item the subject was observed always (right or left), usually (right or left), or either. Responses of either received zero points, always right two points, and usually right one point. Responses of always left received negative two points and usually left received negative one point. The sum was divided by the number of questions observed (some children did not know how to perform some of the items, like light a match) times two because two is the total number of possible points per item. If the quotient was above 0.75 they are considered strongly right handed and if it was below -0.75, they were

strongly left handed. Participants were classed as right-handed if they wrote with their right hand and had a quotient of .75 or greater. All others were classed as non-right (see Tables 5, 10, and 16).

Socioeconomic Status

Socioeconomic status was calculated using the Hollingshead four factor index of social status (Hollingshead, 1975). Information on parent education and occupation was obtained and rated on a scale of one to seven and one to nine respectively. If the child came from a single-parent household or a single-earner household, the score was calculated using the working parent's occupation. However, if both parents worked, the scores were added together and then averaged.

Phonemic Awareness

Two measures of phoneme manipulation were chosen to increase construct validity of research question 2 (Cook & Campbell, 1979). The Lindamood Auditory Conceptualization test (LAC) and the Elision test were chosen as measures of phoneme manipulation. The LAC uses blocks to represent sounds and the participant manipulates the blocks to represent speech sounds provided by the examiner. The Elision test is presented in the form of a word game where the child verbally manipulates the sounds. The Incomplete Words test was chosen as a task of phoneme closure, which provided a measure of another aspect of phonemic awareness. The assessment measures are described fully in the following paragraphs.

The Lindamood Auditory Conceptualization test (LAC), an individually administered test, was designed to evaluate children's ability to discriminate speech sounds as well as to perceive the number and order of sounds within a spoken pattern.

The LAC measures phonological awareness and phonetic recoding in working memory. The test is designed for use with children in Kindergarten through 12^{th} grade to aid in the identification of auditory perceptual deficiencies. The standardization sample was 660 Kindergarten through 12th-grade boys and girls from a large heterogeneous California school district. Alternate-form reliability is high (r=.96). No information is available about within-grade reliabilities. Correlations between the combined reading and spelling subtests of the Wide Range Achievement Test and the LAC range from .66 to .81 with a median of .75 (Sattler, 1992). After 6^{th} grade, participants are expected to score between 99 and 100.

The Elision task from Torgesen's unpublished battery of phonemic awareness tasks was given (Torgesen, 1993). Wagner, Torgesen, and Rashotte (1999) recently published a battery of phonological processing which contains a nearly identical version of the Elision task used in the current study. The test's 25 items require the participants to manipulate word segments and phonemes by omitting and deleting them to make new words. The Elision task measures phonological awareness and phonetic recoding in working memory. As previously mentioned, as children develop, they demonstrate awareness for increasingly smaller units of speech. Performance on the Elision task correlates with later reading achievement after controlling for IQ. Reliability information for the specific task administered is not available. The test-retest reliability coefficient for the recently published (Wagner et al., 1999) Elision task for children between five and seven years of age is high (r = .88).

The Incomplete Words subtest from the Woodcock-Johnson Psychoeducational Battery-Revised was given (Woodcock & Johnson, 1989). This subtest measures

auditory closure, or the ability to identify a word when provided only some of the sounds within it. This test is presented with a tape player and progresses in difficulty from words missing single phonemes to words missing multiple phonemes.

<u>Rapid naming</u>

The Rapid Automatic Naming Task (RANT) is an additional measure of phonological processing, specifically, phonological recoding in lexical access. The rapid naming of colors, numbers, and letters requires efficient retrieval of phonological information from long-term memory. While reading, children must retrieve phonemes associated with letters in an efficient and fluent fashion. The efficiency with which children are able to retrieve phonological codes associated with individual phonemes should influence the degree to which phonological information is useful when decoding printed words. The ability of younger children to rapidly name may be limited given their unfamiliarity with digits and numbers. Younger children are asked to name common colors because rapid naming tasks should be designed to measure differences in the rate of naming familiar qualities, not differences in the familiarity of things to be named. However, rapid naming of digits and letters is more predictive of reading than is rapid naming of colors (Wagner, Torgesen, & Rashotte 1999). The ability to name colors, numbers, and letters rapidly has been associated with reading achievement (Blachman, 1984; Cronin & Carver, 1998). The ability to rapidly name colors was predictive of reading achievement in kindergarten, and rapid naming of letters and colors were significant predictors of reading achievement in first grade (Blachman, 1984).

A set of colors, uppercase letters, and numbers were presented on laminated 8" by 10" cards were presented to the child who was told to name the items as quickly as he or

she could. Prior to the timed trial, the child is tested to determine whether he or she knew the colors, letters, and numbers being presented. If the child did not know the colors, letters, or digits presented on the card, the trial for the unknown items was omitted. The amount of time required for each type of stimulus was recorded.

Reliability information for the particular items administered is not available. However, Wagner, Torgesen, and Rashotte's (1999) recently published battery of phonological processing which contains a nearly identical version of the Rapid Automatic Naming task used in the current study. The test-retest reliability coefficients for the Rapid Naming task for Color (r = .78), Digits (r = .91), and Letters (r = .97) are high.

Emergent Reading Measures

The relationship between reading instruction and phonemic awareness is bi-directional (Barron, 1991; Bentin et al., 1992; Foorman, 1995; Perfetti et al., 1987; Wagner et al., 1997) and phonemic awareness skills are predictive of later reading ability (Lundberg et al., 1980; MacDonald & Cornwall, 1995; Salonen et al., 1998; Snider, 1997; Torgesen et al., 1994). The Letter-Word Identification, Word Attack, Passage Comprehension, and Early Reading Screening Inventory were chosen to measure various aspects of reading achievement and reduce the threat of construct underrepresentation (Cook & Campbell, 1979). The battery includes a test of letter and sight word identification, reading comprehension, an inventory of basic reading skills, and a nonsense word reading task. These tasks were selected as they represent age appropriate measures of reading skill.

The Early Reading Screening Inventory (ERSI) was administered to assess basic reading skills (Lombardino, Morris, Mercado, Defillipio, Sarisky, & Montgomery, 1999).

The ERSI consists of four subtests, Alphabet Knowledge, Concept of Word, Invented Spelling, and Word Recognition. The Alphabet Knowledge subtest measures a child's skills in naming visually presented upper and lower case letters and the ability to write the letters when they are presented orally. The Concept of Word subtest requires the child to identify a word in the context of a story. Invented Spelling requires the child to spell 12 words, which consist of three or four phonemes. The Word Recognition subtest assesses a child's ability to read 20 consonant-vowel-consonant words. The four subtests are combined to provide an index of reading skill. The maximum score is 40.

The Word Attack, Letter-Word Identification, and Passage Comprehension subtests from the Woodcock-Johnson Psychoeducational Battery-Revised (WJ-R) were used to test reading skills and performance (Woodcock & Johnson, 1989). The Word Attack and Letter-Word Identification subtests also are considered indices of phonemic awareness.

The WJ-R was normed with 6359 participants in over 100 geographically diverse US communities. Participants were selected randomly within a stratified sampling design that was consistent with the population distribution of the 1980 census. Items selected for inclusion in the measure were chosen through expert opinion and ultimately validity studies. The correlations of achievement measures to other measures of achievement are typically .60 and .70 at the age 9 and 17 levels. Raw scores on each subset were converted to standard scores.

The Word Attack subtest measures the ability to apply phonemic and structural analysis skills when pronouncing phonetically regular nonsense words. All nonsense words follow the patterns of regular English pronunciation and spelling. To decode the

word, a student must remember the phoneme associated with each sound and then blend or synthesize the phonemes into a word. The successful identification of the multisyllabic nonsense words requires increased knowledge of word structure. The split-half reliability of the Word Attack subtest is .91.

Letter-Word Identification measures the ability to identify letters and words. The items progress from rebuses, to individual letters, to high frequency words, to words that appear less frequently in written English. The split-half reliability of the Letter-Word Identification subtest is .91.

Passage Comprehension measures an individual's ability to use syntactic and semantic clues to identify a key word missing from a passage. The split-half reliability of the Passage Comprehension subtest is .90.

Intellectual Ability

The Woodcock-Johnson Revised Standard Cognitive Battery was administered to ensure that the participants had normal intelligence. The WJ-R Cognitive Standard Battery is comprised of seven subtests: Memory for Names, Memory for Sentences, Visual Matching, Incomplete Words, Visual Closure, Picture Vocabulary, and Analysis-Synthesis. The WJ-R Cognitive Battery was normed with 6,359 participants in over 100 geographically diverse US communities. Participants were selected randomly within a stratified sampling design that was consistent with the population distribution of the 1980 census. Items selected for inclusion in the measure were chosen through expert opinion and ultimately validity studies. In general, the split-half reliability of the individual subtests is quite high (e.g., the high .80s and low .90s). The correlations between the Broad Cognitive Cluster and other measures of cognitive ability (e.g., Kaufman

Assessment Battery for Children, Stanford-Binet IV, and the Wechsler Intelligence Scale for Children –III) typically are in the .60 to the .70 range.

MRI Scan

Two scan sequences were performed in a Siemens 1 Tesla Magnetom using a quadrature head coil: (1) a gradient echo volumetric acquisition "Turboflash" MP Rage sequence that is transferred into a volumetric gapless series of 128 1.25-mm thick images in the sagittal plane; and (2) a traditional axial scan of 5-mm T2 spin and density weighted images separated by 2.5 mm gaps. No gaps exist in the volumetric data from the gradient echo scan. Thus, the data can be reconstructed into a set of images in any plane. The images were transferred to a computer workstation, where they were displayed and analyzed with programs written in PV Wave.

MRI and Children

Giedd (1997) discusses methodological issues pertinent to pediatric magnetic resonance Imaging (MRI) of the brain:

> MR imaging uses no ionizing radiation, it offers the capacity to acquire images in any plane of view with excellent spatial resolution, and it provides a good contrast between gray matter, white matter, and cerebrospinal fluid (CSF). As opposed to conventional radiography and CT, which rely solely in radiograph patency, MR imaging can assess a variety of tissue characteristics, and it can be used to visualize structures such as temporal lobes, frontal lobes, and posterior fossa, which are often obscured by bone interference on CT scans. These characteristics make MR imaging the imaging modality of choice for pediatric neuroimaging studies. (p. 265).

<u>Brain Measurements</u>

A standard set of measurements was obtained for each brain. A mouse was used to trace the length in millimeters (mm) of the structure on every volumetric section. These measurements then were averaged in order to obtain a mean, standard deviation, and the degree of asymmetry. The total surface area of the structure was determined by multiplying the length by the section thickness (i.e., recall that the MRI data are transferred into 1.25 mm thick images). The total brain volume of each child's brain was determined and was reported in cubic millimeters. The surface area of the horizontal planum temporale was traced on consecutive sagittal images. The horizontal and vertical (ascending) banks of the planum temporale were measured separately. The degree of asymmetry between the horizontal planum temporale measurements of the right and left hemispheres was determined and reported as a coefficient. The formula for determining the planar asymmetry coefficient is: $(l-r) / ((l + r)/2)$.

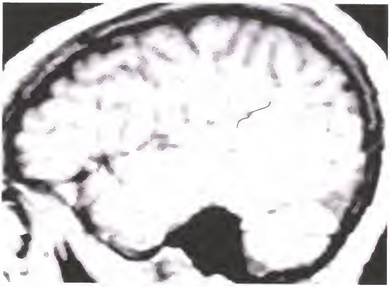

Figure 6. Sagittal Image of the Human Brain Outlining the Horizontal Branch of the Planum Temporale.

Table 1

Areas Assessed and Instruments Used

Assessment Area	Instrumentation	Unit of Measure
Handedness	Modified Edinburgh Battery	Quotient (.75 ≥ Right Handed) (.75 < Non-Right)
Phonemic Awareness	Lindamood Auditory Conceptualization Test (LAC)	Total Score (Maximum = 100)
	Elision Task	Total Score (Maximum = 25)
	Incomplete Words	Standard Score
Emergent Reading	Word Attack	Standard Score
	Letter-Word Identification	Standard Score
	Passage Comprehension	Standard Score
	Early Reading Screening Inventory (ERSI)	Total Score (Maximum = 40)
Rapid Naming	Rapid Automatic Naming Task (RANT)	
	Colors	Time in Seconds
	Letters	Time in Seconds
	Digits	Time in Seconds
Intellectual Ability	Woodcock-Johnson Psychoeducational Battery—Revised, Tests of Cognitive Ability, Standard Battery	Standard Score

Statistical Analyses

Descriptive Statistics and Reliability

The descriptive statistics were determined for all data sets. Reliability estimates for the brain measurements were calculated using a product moment correlation.

Hypothesis Testing

Recall that the three broad research questions are as follows: 1) Is the leftward asymmetry of the horizontal planum temporale associated positively related with phonemic awareness skills? 2) Is the leftward asymmetry of the horizontal planum temporale associated positively with emergent reading skills in young children, and 3) Is the leftward asymmetry of the horizontal planum temporale related positively with phonological recoding in lexical access as measured by the rapid naming tasks? Relationships between the independent variables and the three dependent variables were examined using individual hypotheses.

A series of explanatory multiple regression models were conducted to test each research question. The independent variable was the degree of asymmetry between the left and right horizontal planum temporale measurements, after controlling for gender, handedness, IQ, and socioeconomic status. Multiple dependent variables represented the three constructs of interest examined by the three research questions: phonemic awareness (i.e., LAC, Elision task, and Incomplete Words), emergent reading (i.e., Word Attack, Letter-Word Identification, Passage Comprehension, the Early Reading Screening Inventory), and rapid automatic naming (i.e., colors, letters, and digits). The use of multiple dependent variables to represent a single construct allows one to measure

different aspects or levels of the aforementioned constructs and therefore decrease the likelihood of construct underrepresentation, a first step toward construct validity (Cook & Campbell, 1979).

A separate regression equation, then, corresponds to each of the dependent variables, resulting in a series of regression analyses, several being implemented for each research question (i.e., construct): three for phonemic awareness, four for emergent reading, and three for phonological recoding in lexical access. All regression analyses that were associated with the same construct (i.e., phonemic awareness, emergent reading, and phonological recoding in lexical access) were grouped together conceptually and treated as a "family" of statistical analyses. To maintain the familywise Type I error at $\alpha = .05$, a Bonferroni adjustment was applied to each of the three "families" of analyses. Multicollinearity of the independent variables was examined using the SPSS Condition Index, C. If this Condition Index had exceeded 30, corrective action would have been taken to obtain an acceptable level of multicollinearity. Multicollinearity was acceptable (<30) for all hypotheses tested.

Gender, handedness, intelligence, and socioeconomic status were controlled statistically through inclusion in the equation. When more than two horizontal planar measurements existed for a participant, the individual measurements were averaged together to provide the best estimate of the length of the horizontal planum temporale.

A power analysis was conducted to aid in the interpretation of the data. The probability of rejecting a null hypothesis when it is false is referred to as the power of a test, with high power being desirable. The probability of Type II error is decreased by selecting a larger sample when there is a fixed probability of Type I error. That is, the

larger the sample size, the more likely we are to reject a false null hypothesis at a particular α-level. The use of large sample sizes decreases the probability of Type I and Type II errors.

An insignificant P-value and failure to reject the null hypothesis may be due to insufficient power for the size of the sample used. The post hoc estimation of power facilitates an interpretation of one's results. Researchers not sufficiently sensitive to power may interpret nonsignificant results as demonstrating no relationship or treatment effects. A relationship may exist, yet inadequate power may result from small sample size and/or effect sizes. That is, a relationship or a treatment effect may exist, yet the power for detecting the difference was inadequate.

The current study utilizes sample sizes ranging from 41 to 58. These sample sizes are relatively low for behavioral science research, yet higher than those typically found in neuroscience research. Larger sample sizes contribute to the probability of higher power. Thus, the lower power associated with relatively low sample sizes accounts in part for a lack of significant results in the data.

Outliers

Multivariate outliers were removed within each family of variables. SPSS regression was used to screen for multivariate outliers within each family. The criterion for multivariate outliers was Mahalanobis distance. Mahalanobis distance is evaluated as χ^2 at $p<.001$ with the degrees of freedom equal to the number of variables. Any case with a Mahalanobis distance greater than the specified χ^2 was considered a multivariate outlier with too much influence in the analysis and was removed.

Table 2

Independent and Dependent Variables Examined

Independent Variable	Dependent Variable Family Name
Horizontal Planar Asymmetry	Emergent Reading Phonemic Awareness Rapid Naming

CHAPTER 4
RESULTS

Overview of Analyses and Results

This research examined relationships between one independent variable (i.e., leftward horizontal planar asymmetry) and three dependent variables (i.e., phonemic awareness, emergent reading, rapid naming skills) in young children. Relationships between the independent variables and the three dependent variables were examined with individual hypotheses. Data were incomplete on some of the 58 children. Data on children were included in an analysis only if complete data were available on them in the construct family being investigated. This process ensured that the sample size was kept at its maximum for each analysis within each of the families and led to the creation of subsets with varying sizes. The number of participants used for each research question is reported in the results for that hypothesis.

Reliability is the accuracy or precision of a measuring instrument. In the current study, interrater reliability was the consistency of planum temporale measurements when measured by different individuals. Intrarater reliability in the present study was defined as the author's consistency in measuring the planum temporale across time. The interrater (n=8) and intrarater (n=16) reliability estimates were adequate and are reported in Table 3.

Table 3

Intrarater and Interrater Reliability for Neuroanatomical Measurements

Structure	Intrarater Reliability $n = 16$	Interrater Reliability $n = 8$
Planum Temporale		
Left Horizontal	.98	.98
Right Horizontal	.95	.90
Left Ascending	.97	.98
Right Ascending	.90	.97

A correlation matrix reporting relationships between the control variables and the left horizontal planum, right horizontal planum, and the subsequent horizontal planar coefficient indicates that gender, handedness, IQ, and socioeconomic status (SES) are not significantly related to horizontal planar asymmetry.

Table 4

Horizontal Planar Measurements and Asymmetry Coefficient Correlations with Control Variables ($n = 58$)

	Correlation Coefficients			
	Gender	Handedness	IQ	SES
Horizontal Planar Coefficient	-.03	-.16	.03	.07
Left Horizontal Planum	-.08	-.20	-.10	.06
Right Horizontal Planum	-.03	.03	-.13	.02

Hypothesis Testing

Research Question 1

Is the leftward asymmetry of the horizontal planum temporale (i.e., horizontal planar coefficient) associated positively with pre-reading skills, specifically phonemic awareness among young children? This research question was analyzed using three hypotheses.

Hypothesis 1:1 Leftward asymmetry of the horizontal planum temporale was expected to be positively related to the ability to manipulate phonemes as measured by the Lindamood Auditory Conceptualization test (LAC.)

Hypothesis 1:2 Leftward asymmetry of the horizontal planum temporale was expected to be positively related to the ability to manipulate phonemes as measured by the Elision task.

Hypothesis 1:3 Leftward asymmetry of the horizontal planum temporale was expected to be positively related to auditory closure as measured by the Incomplete Words test.

The independent variable is the horizontal planar coefficient and the dependent variables are reflected in the Lindamood Auditory Conceptualization Test (LAC), Elision Task, and the Incomplete Words test.

The SPSS regression analysis revealed no multivariate outliers that exceeded the Mahalanobis distance χ^2 (4) = 18.47. Therefore, the Phonemic Awareness family has an *n* of 58. Table 5 presents a description of data from this subset of participants.

Table 5

Descriptive Statistics for the Phonemic Awareness Family (n=58)

Variable	n	%	Mean	SD	Range
Gender					
Boys	32	55			
Girls	26	45			
Race/Ethnicity					
African American	13	22			
Asian	1	2			
Caucasian	43	74			
Native American	1	2			
Handedness					
Right	31	53			
Non-Right	27	47			
Age			6.1	0.4	5.1 – 7.2
Socioeconomic Status			46.9	15.1	13 – 66
Brain Volume			1187	101	990 –1475
Lindamood Auditory Conceptualization Test			39	11	20 - 76
Elision			8	4	3 - 19
Incomplete Words			98	10	73 - 133

Table 6 reports the correlation matrix of all variables of interest for Hypothesis One. The horizontal planar coefficient was expected to correlate positively with the dependent variables (i.e., Elision, LAC, and Incomplete Words). No variables correlate with the horizontal planar coefficient. The LAC and Incomplete Words tests correlate

with IQ, a variable controlled in the analysis. No other control variables are correlated with the dependent variables.

Table 6

Phonemic Awareness Variable Family Correlation Matrix (*n*=58)

	LAC	Elision	IncWords	Gender	Hand	IQ	SES
Planar Coefficient	-.02	.17	.14	-.02	-.17	.02	.06
Left Planum	-.26*	.06	-.07	-.07	-.20	-.11	.05
Right Planum	-.21	-.19	-.15	.01	.04	-.15	-.01
LAC	--	.41**	.15	.21	-.03	.52**	-.05
Elision		--	-.04	.15	.09	.14	-.14
Incomplete Words			--	.03	.18	.47**	.18
Gender				--	.05	-.11	-.20
Handedness					--	.06	.06
IQ						--	.05

Note. LAC = Lindamood Auditory Conceptualization Test; Inc Words = Incomplete Words; Hand = Handedness; IQ = Intelligence Quotient; SES = Socioeconomic Status. * $p \leq .05 > .01$. ** $p \leq .01$

Hypothesis testing associated with research question 1 would be supported if the horizontal planar coefficient were associated positively with the three measures of

phonemic awareness. It would not be supported if a relationship between phonemic awareness and the horizontal planar coefficient were not found or was negative. Results are reported below.

Hypothesis 1:1 Elision test (phoneme manipulation). The horizontal planar coefficient was expected to be associated positively with the ability to manipulate phonemes (i.e., one of the five levels of phonemic awareness) as measured by the Elision test. The regression analysis for this variable is reported in Table 7.

Table 7

Elision Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	.97	1.0	.30	.07	.00
Handedness	.77	.85	.40		
IQ	.05	1.2	.24		
Socioeconomic Status	-.03	-.99	.33		
Horizontal Planar Coefficient	1.56	1.5	.14	.11	.02
Constant	3.17	.74	.47		
					R^2 = .11 Adjusted R^2 = .02

To predict the relationship between the ability to manipulate phonemes and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient as the independent variable. The control variables accounted for 7% of the variance within the Elision

scores, and the horizontal planar coefficient provided an additional 4%. The change in R^2 when the horizontal planar coefficient was added to the model was not significant (F (1,52) =2.25, p=.14). The variables in the equation are represented as follows:

$$\widehat{\text{(Elision)}} = 3.17 + \text{Gender}(.97) + \text{Handedness}(.77) + \text{IQ}(.05) + \text{Socioeconomic Status}(-.03) + \text{Horizontal Planar Coefficient}(1.56).$$

The regression equation was not significant (F (5,58) =1.23, p=.31) and the Adjusted R^2 is low, .02. Therefore, horizontal planar asymmetry does not predict the ability to manipulate phonemes as measured by the Elision test. Thus, hypothesis 1:1 is not supported by this analysis.

Hypothesis 1:2 Lindamood Auditory Conceptualization test (phoneme manipulation). Horizontal planar coefficient was expected to be associated positively with the ability to manipulate phonemes (i.e., one of the five levels of phonemic awareness) as measured by the Lindamood Auditory Conceptualization test (LAC). The regression analysis for this variable is reported in Table 8.

To predict the relationship between the ability to manipulate phonemes and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables combined to significantly predict phoneme manipulation, and collectively contributed 35% to the variance of phoneme manipulation as measured by the LAC (Table 8). Males scored higher on the LAC test than females (i.e., Males were coded as 1 and Females as 0.) A participant is predicted to earn .49 points on the LAC for every point of IQ.

Table 8

Lindamood Auditory Conceptualization Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	5.8	2.4	.02	.35	.30
Handedness	-1.8	-.76	.45		
IQ	.49	4.9	<.01		
Socioeconomic Status	-.01	-.11	.91		
Horizontal Planar Coefficient	-1.0	-.39	.70	.35	.29
Constant	-13.6	-1.2	.23		
					R^2 =.35 Adjusted R^2 = .29

The change in R^2 when the horizontal planar coefficient was added to the model was not significant (F (1,52) =.15, p=.70). The variables in the equation are represented as follows:

$$\widehat{(LAC)} = -13.6 + \text{Gender}(5.8) + \text{Handedness}(-1.8) + \text{IQ}(.49) + \text{Socioeconomic Status}(-.01) + \text{Horizontal Planar Coefficient}(-1.0).$$

The regression equation created to test this hypothesis was significant (F (5, 58) = 5.64, $p < .01$). The addition of the horizontal planar coefficient did not change the amount of variance contributed to the equation, nor was it a significant predictor of the horizontal planar coefficient. Thus, hypothesis 1:2 was not supported by this analysis.

Hypothesis 1:3 Incomplete Words Test (auditory closure). The horizontal planar coefficient was expected to be associated positively with auditory closure for missing phonemes as measured by the Incomplete Words subtest of the WJ-R. The regression analysis for this variable is reported in Table 9.

To predict the relationship between auditory closure for missing phonemes and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent

Table 9

Incomplete Words Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	2.4	.99	.33	.26	.21
Handedness	1.4	.59	.56		
IQ	.39	3.9	<.01		
Socioeconomic Status	.11	1.4	.16		
Horizontal Planar Coefficient	3.0	1.1	.26	.28	.21
Constant	49.8	4.5	<.01		
				R^2 =.28 Adjusted R^2 = .21	

variable. The control variables accounted for 26% of the variance within Incomplete Words scores and the horizontal planar coefficient provided an additional 2%. A participant is predicted to earn .39 points for every point of IQ. The change in R^2 when

the horizontal planar coefficient was added to the model was not significant ($\underline{F}$ (1,52) = 1.30, p=.26). The variables in the equation are represented as follows:

$$\widehat{\text{(Incomplete Words)}} = 49.8 + \text{Gender}(2.4) + \text{Handedness}(1.4) + \text{IQ}(.39) + \text{Socioeconomic Status}(.11) + \text{Horizontal Planar Coefficient}(3.0).$$

The regression equation created for the Incomplete Words test was significant ($\underline{F}$ (5, 58) = 4.03, p < .01). The addition of the horizontal planar coefficient made a 2% change in the amount of variance contributed to the equation, and was not a significant predictor. Thus, hypothesis 1:3 was not supported by this analysis.

Bonferroni Adjustment. A Bonferroni adjustment was applied to maintain the familywise Type I error at $\alpha = .05$ for research question 1. The equation was as follows for the phonemic awareness family: .05 / 3 = .017. The equations that include the ability to manipulate phonemes (as measured by the LAC test) and auditory closure for missing phonemes (as measured by the Incomplete Words test) remained significant with the Bonferroni correction.

Summary of Research Question 1. The horizontal planar coefficient was expected to be associated positively with phonemic awareness skills. Although two of the three regression equations within the phonemic awareness family were significant, research question 1 was not supported. The model testing whether the horizontal planar coefficient predicts phoneme manipulation, as measured by the Elision task, was not significant. The model testing phoneme manipulation as measured by the LAC was significant, but horizontal planar asymmetry was not a significant predictor. The only

significant predictors of variance in the model were gender and IQ. The third model, in which the horizontal planar coefficient was expected to predict auditory closure for missing phonemes as measured by the Incomplete Words test of the WJ-R, was significant. However, the horizontal planar coefficient was not a significant predictor.

Research Question 2

Is the leftward asymmetry of the horizontal planum temporale (i.e., horizontal planar coefficient) associated positively with emergent reading skills among young children? This research question will be analyzed using four hypotheses.

Hypothesis 2:1 The horizontal planar coefficient was expected to be positively related to the ability to identify letters and words as measured by the Letter-Word Identification test of the WJ-R.

Hypothesis 2:2 The horizontal planar coefficient was expected to be positively related to the ability to read nonsense words as measured by the Word Attack subtest of the WJ-R.

Hypothesis 2:3 The horizontal planar coefficient was expected to be positively related to basic reading skills as measured by the Early Reading Screening Inventory.

Hypothesis 2:4 The horizontal planar coefficient was expected to be positively related to reading comprehension skills as measured by the Passage Comprehension Test.

The independent variable was the horizontal planar coefficient and the dependent variables were Word-Attack, Letter-Word Identification, Passage Comprehension, and the Early Reading Screening Inventory (ERSI.)

The SPSS regression analysis revealed one multivariate outlier that exceeded the Mahalanobis distance χ^2 (5) = 20.50. This case was removed and not included in the

analysis of the emergent reading family, resulting in an *n* for this hypothesis of 55. Table 10 presents a description of data from this subset of participants.

Table 10

Descriptive Statistics for the Emergent Reading Family

Variable	*n*	%	Mean	SD	Range
Gender					
Boys	30	55			
Girls	25	46			
Race/Ethnicity					
African American	12	22			
Asian	1	2			
Caucasian	41	75			
Native American	1	2			
Handedness					
Right	30	55			
Non-Right	25	46			
Age			6.1	0.4	5.1 – 7.2
Socioeconomic Status			47	15	13 – 66
Brain Volume			1187	101	990 –1475
Letter-Word Identification			100	13	64 – 123
Word Attack			96	11	77 – 124
Early Reading Screening Inventory (ERSI)			27	9	4 – 40
Passage Comprehension			101	14	74 – 132

Table 11

Emergent Reading Variable Family Correlation Matrix
(*n*=55)

	LW	WA	PC	ERSI	IQ	SES	Gender	Hand
Planar Coefficient	.44**	.24	.30*	.30*	.02	.07	.01	-.12
Left Planum	.17	-.01	.15	.02	-.10	.05	-.08	-.20
Right Planum	-.37**	-.30*	-.2	-.34**	-.14	.04	-.04	-.03
Letter-Word Identification	--	.48**	.63**	.77**	.43**	-.04	.02	.02
Word-Attack		--	.45**	.37**	.28*	.07	.01	.07
Passage Comprehension			--	.32*	.46**	.06	.01	.02
Early Reading Screening Inventory				--	.43**	-.15	-.05	.10
IQ					--	.04	-.10	.07
Socioeconomic Status						--	-.19	.11
Gender							--	-.02

Note. LW = Letter-Word Identification; WA = Word Attack; PC = Passage Comprehension; ERSI = Early Reading Screening Inventory; IQ = Intelligence Quotient; SES = Socioeconomic Status; Hand = Handedness.

$^{*}\ p \leq .05 > .01$. $^{**}\ p \leq .01$

As expected, data from Letter-Word Identification, Passage Comprehension, and the Early Reading Screening Inventory (ERSI) were correlated with horizontal planar coefficient (Table 11). However, Word Attack was expected to but did not correlate with the horizontal planar coefficient. The four dependent variables were correlated with IQ, a variable controlled in the analysis.

Hypothesis testing associated with research question 2 would be supported if the horizontal planar coefficient were related positively with the three measures emergent reading skills. It would not be supported if a relationship between leftward horizontal planar asymmetry and emergent reading skills is not found or is negative.

Hypothesis 2:1 Letter-Word Identification (letter and sight word reading). Horizontal planar coefficient was expected to be associated positively with letter and word identification skills as measured by Letter-Word Identification. The regression analysis for this variable is reported in Table 12.

To predict the relationship between letter and word identification skills and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables accounted for 19% of the variance within Letter-Word Identification scores and the horizontal planar coefficient provided an additional 19%. Both IQ and the horizontal planar coefficient explained a significant amount of variance. A participant is predicted to earn .44 Letter-Word Identification points for every point of IQ.

Table 12

Letter-Word Identification Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	1.24	.43	.67	.19	.12
Handedness	1.22	.41	.69		
IQ	.44	3.74	<.01		
Socioeconomic Status	-.05	-.55	.58		
Horizontal Planar Coefficient	12.44	3.92	<.01	.38	.32
Constant	53.36	4.06	<.01		

R^2 =.38
Adjusted R^2 = .32

The change in R^2 when the horizontal planar coefficient was added to the model was significant (F (1,49) = 15.35, $p < .01$). The variables in the equation are expressed as follows:

$$\widehat{\text{(Letter-Word Identification)}} = 53.36 + \text{Gender}(1.24) + \text{Handedness}(1.22) + \text{IQ}(.44) + \text{Socioeconomic Status}(-.05) + \text{Horizontal Planar Coefficient}(12.44)$$

The regression equation created for the Letter-Word Identification was significant (F (5, 55) = 6.05, $p < .01$). Leftward asymmetry of the horizontal planum temporale was

positively related to the ability to identify letters and words. Thus, hypothesis 2:1 was supported by this analysis.

Hypothesis 2:2 Word Attack (reading phonetically regular nonsense words). The horizontal planar coefficient was expected to be associated with the ability to read phonetically regular nonsense words, as measured by the Word Attack subtest. The regression analysis for this variable is reported in Table 13

Table 13

Word-Attack Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	1.13	.37	.71	.09	.02
Handedness	1.73	.54	.59		
IQ	.25	2.0	.05		
Socioeconomic Status	.04	.40	.69		
Horizontal Planar Coefficient	6.2	1.84	.07	.14	.06
Constant	64.9	4.66	<.01		

$R^2 = .14$
Adjusted $R^2 = .06$

To predict the relationship between the ability to read phonetically regular nonsense words and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables accounted for 9% of the

variance within Word Attack scores and the horizontal planar coefficient provided an additional 5% of the variance. A participant is predicted to earn .25 points for every point of IQ. The change in R^2 when the horizontal planar coefficient was added to the model approached significance (F (1,49) = 3.39, p = .07). The variables in the equation are represented as follows:

$$\widehat{(\text{Word-Attack})} = 64.9 + \text{Gender}(1.13) + \text{Handedness}(1.73) + \text{IQ}(.25) + \text{Socioeconomic Status}(.04) + \text{Horizontal Planar Coefficient}(6.2)$$

The regression equation created was not significant (F (5,55) = 1.65, p = .16). Thus, hypothesis 2:2 was not supported by this analysis.

Hypothesis 2:3 Early Reading Screening Inventory (basic reading skills). The horizontal planar coefficient was expected to be associated with early reading skills as measured by the Early Reading Screening Inventory (ERSI). The regression analysis for this variable is reported in Table 14.

To predict the relationship between letter and word identification skills and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables accounted for 23% of the variance within the ERSI scores, and the horizontal planar coefficient provided an additional 9%. A participant is predicted to earn .32 points for every point of IQ. The change in R^2 when the horizontal planar coefficient was added to the model was significant (F (1,49) = 6.77, $p \leq .01$).

The variables in the equation are represented as follows:

$$\widehat{(\text{ERSI})} = -2.70 + \text{Gender}(-.84) + \text{Handedness}(2.42) + \text{IQ}(.32) + \text{Socioeconomic Status}(-.12) + \text{Horizontal Planar Coefficient}(6.34).$$

Table 14

Early Reading Screening Inventory

Variable	β	t	p	R^2	Adjusted R^2
Gender	-.84	-.38	.70	.23	.16
Handedness	2.42	1.05	.30		
IQ	.32	3.57	p<.01		
Socioeconomic Status	-.12	-1.64	.12		
Horizontal Planar Coefficient	6.34	2.61	.01	.32	.25
Constant	-2.70	-.27	.79		
					R^2 =.32 Adjusted R^2 = .25

The equation created was significant ($\underline{F}$ (5, 55) = 4.61, $p < .01$). The horizontal planar coefficient explained a significant amount of variance. Leftward asymmetry of the horizontal planum temporale was positively related to early reading skills. The control variables, particularly IQ, were also significant predictors. Thus, hypothesis 2:3 was supported by this analysis.

Hypothesis 2:4 Passage Comprehension (reading comprehension). The horizontal planar coefficient was expected to be associated with reading comprehension skills as

measured by the Passage Comprehension subtest. The regression analysis for this variable is reported in Table 15.

Table 15

Passage Comprehension

Variable	β	t	p	R^2	Adjusted R^2
Gender	1.78	.53	.60	.22	.15
Handedness	.57	.16	.87		
IQ	.53	3.79	p<.01		
Socioeconomic Status	.03	.29	.77		
Horizontal Planar Coefficient	8.88	2.38	p<.02	.30	.23
Constant	42.7	2.76	p<.01		
					R^2 =.30 Adjusted R^2 = .23

To predict the relationship between reading comprehension and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables accounted for 22% of the variance within Passage Comprehension scores and the horizontal planar coefficient provided an additional 8%. A participant is predicted to earn .53 points on the Passage Comprehension test for every point of IQ. The change in R^2 when the horizontal planar coefficient was added to the model was significant ($\underline{F}$ (1,49) = 5.66, p = .02).

The variables in the equation are represented as follows:

$$\widehat{\text{(Passage Comprehension)}} = 42.7 + \text{Gender}(1.78) + \text{Handedness}(.57) + \text{IQ}(.53) + \text{Socioeconomic Status}(.03) + \text{Horizontal Planar Coefficient}(8.88).$$

The equation created was significant ($\underline{F}$ (5, 55) = 4.16 , $p < .01$). Leftward asymmetry of the horizontal planum temporale was positively related to reading comprehension. IQ, in conjunction with the other control variables was also a significant predictor. Thus, hypothesis 2:4 was supported by this analysis.

Bonferroni Adjustment. A Bonferroni adjustment was applied to maintain the familywise Type I error at $\alpha = .05$ for research question 2. The equation was as follows for the emergent reading family: .05 / 4 = .0125. The equations that include letter and word identification skills (as measured by the Letter-Word Identification test), early reading skills (as measured by the Early Reading Screening Inventory), and reading comprehension skills (as measured by the Passage Comprehension test) remained significant with the Bonferroni correction.

Summary of Research Question 2. Leftward horizontal asymmetry of the planum temporale, as measured by the horizontal planar coefficient, was expected to predict emergent reading skills. Three of the four hypotheses within the emergent reading family were significant. Thus, research question two was partially supported. The model testing whether leftward horizontal planar asymmetry predicts the ability to read phonetically regular nonsense words was not significant. The horizontal planar coefficient in

conjunction with IQ explained 32% of the variance in the ability to read letters and words. Twenty-five percent of the variance in early reading skills was explained by the horizontal planar coefficient and the control variables, particularly IQ. The horizontal planar coefficient and IQ explained 23% of the variance in reading comprehension. Thus, partial support for research question 2 was found.

Research Question 3

Leftward asymmetry of the horizontal planum temporale (i.e., horizontal planar coefficient) associated positively with Rapid Automatic Naming Skills? This research question will be analyzed using the following three subhypotheses.

Hypothesis 3:1 The horizontal planar coefficient was expected to be positively related with the ability to name colors rapidly.

Hypothesis 3:2 The horizontal planar coefficient was expected to be positively related with the ability to name numbers rapidly.

Hypothesis 3:3 The horizontal planar coefficient was expected to be positively related with the ability to name letters rapidly.

A regression equation was created for this research question, Rapid Naming, with the independent variable being the horizontal planar coefficient and the dependent variables being three rapid naming tasks for colors, letters, and numbers.

The SPSS regression analysis revealed one multivariate outlier that exceeded the Mahalanobis distance χ^2 (4) = 18.47, resulting in an *n* for this hypothesis of 41. This case was removed and not included in the analysis of the Rapid Naming family. Table 16 presents a description of data from this subset of participants.

Table 16

Descriptive Statistics for the Rapid Naming Family

Variable	*n*	%	Mean	SD	Range
Gender					
Boys	21	51			
Girls	20	49			
Race/Ethnicity					
African American	9	22			
Asian	1	2			
Caucasian	31	76			
Handedness					
Right	21	51			
Non-Right	20	49			
Age			6.2	0.4	5.1 – 7.2
Socioeconomic Status			45	15	13 – 66
Brain Volume			1181	96	990 –1475
Rapid Naming-Colors			63	22	31 – 126
Rapid Naming –Letters			57	20	30 – 112
Rapid Naming-Numbers			54	20	29– 132

Table 17 reports the correlation matrix of all variables of interest for Hypothesis Three. The horizontal planar coefficient was expected to correlate positively with the dependent variables (i.e., rapid naming of colors, letters, and numbers). However, no variables were correlated with the horizontal planar coefficient. The rapid naming of colors was correlated to SES, a control variable.

Table 17

Rapid Naming Variable Family Correlation Matrix (*n*=41)

	Colors	Numbers	Letters	Gender	Hand	IQ	SES
Planar Coefficient	-.08	-.07	-.17	-.07	-.05	-.01	.11
Left Planum	-.14	-.08	-.02	-.16	-.11	-.15	.11
Right Planum	.01	.05	.20	-.04	-.04	-.12	.03
Colors	--	.65**	.67**	.01	-.15	-.12	.39**
Numbers		--	.80**	.10	.04	-.09	.16
Letters			--	.15	.05	-.14	.24
Gender				--	-.04	.03	-.19
Handedness					--	-.02	-.06
IQ						--	-.13

Note. Hand = Handedness; IQ = Intelligence Quotient; SES = Socioeconomic Status.
* $p \leq .05 > .01$. ** $p \leq .01$

Hypothesis 3:1 Rapid Naming of Colors (phonetic recoding in lexical access). The horizontal planar coefficient was expected to predict the ability to name colors rapidly. The regression analysis for this variable is reported in Table 18.

Table 18

Rapid Naming of Colors Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	2.97	.45	.65	.18	.09
Handedness	-5.66	-.86	.39		
IQ	-.15	-.53	.60		
Socioeconomic Status	.57	2.54	.02		
Horizontal Planar Coefficient	-5.86	-.80	.43	.19	.08
Constant	55.5	1.70	.10		

$R^2 = .19$
Adjusted $R^2 = .08$

To predict the relationship between naming colors rapidly and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables contributed provided for 18% of the variance of Rapid Naming for Colors and the horizontal planar coefficient contributed an additional 1%. The change in R^2 when the horizontal planar coefficient was added to the model was not significant ($\underline{F}$ (1,35) = .64, p = .43).

The variables in the equation are represented as follows:

$$\widehat{\text{(Rapid Naming of Colors)}} = 55.5 + \text{Gender}(2.97) + \text{Handedness}(-5.65) + \text{IQ}(-.15) + \text{Socioeconomic Status}(.57) + \text{Horizontal Planar Coefficient}(-5.86)$$

However, the regression equation created was not significant (F (5, 41) = 1.70, p = .16) and the Adjusted R^2 is low at .08. Thus, hypothesis 3:1 was not supported by this analysis.

Hypothesis 3:2 Rapid Naming of Numbers (phonetic recoding in lexical access). The horizontal planar coefficient was expected to predict the ability to name numbers rapidly. The regression analysis for this variable is reported in Table 19.

Table 19

Rapid Naming of Numbers Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	5.45	.83	.41	.05	-.05
Handedness	2.14	.33	.75		
IQ	-.12	-.42	.68		
Socioeconomic Status	.25	1.14	.26		
Horizontal Planar Coefficient	-3.68	-.50	.62	.06	-.07
Constant	51.0	1.6	.13		

$R^2 = .06$
Adjusted $R^2 = -.07$

To predict the relationship between naming numbers rapidly and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables accounted for 5% of the variance within Rapid Naming of Numbers scores and the horizontal planar coefficient provided an additional 1%. The change in R^2 when the horizontal planar coefficient was added to the model was not significant ($F(1,35) = .25$, $p = .62$). The variables in the equation are represented as follows:

$$\widehat{\text{(Rapid Naming of Numbers)}} = 51.0 + \text{Gender}(5.44) + \text{Handedness}(2.14) + \text{IQ}(-.12) + \text{Socioeconomic Status}(.25) + \text{Horizontal Planar Coefficient}(-3.68).$$

The regression equation created was not significant ($F(5, 41) = .45$, $p = .81$) and the Adjusted R^2 is low at –.07. Thus hypothesis 3:2 was not supported by this analysis.

<u>Hypothesis 3:3 Rapid Naming of Letters (phonetic recoding in lexical access)</u>. The horizontal planar coefficient was expected to predict the ability to name letters rapidly. The regression analysis of this variable is reported in Table 20.

To predict the relationship between naming numbers rapidly and the horizontal planar coefficient, IQ, handedness, gender, and SES were entered into the model as control variables with the horizontal planar coefficient added as the independent variable. The control variables accounted for 11% of the variance within the Rapid Naming of Letters scores and the horizontal planar coefficient provided an additional 4%.

Table 20

Rapid Naming of Letters Equation Summary

Variable	β	t	p	R^2	Adjusted R^2
Gender	7.86	1.22	.23	.11	.01
Handedness	1.64	.26	.80		
IQ	-.19	-.71	.48		
Socioeconomic Status	.39	1.77	.09		
Horizontal Planar Coefficient	-8.54	-1.20	.24	.15	.03
Constant	56.38	1.77	.09		
					$R^2 = .15$ Adjusted $R^2 = .03$

The change in R^2 when the horizontal planar coefficient was added to the model was not significant ($\underline{F}$ (1,35) = 1.42, p = .24). The variables in the equation are represented as follows:

$$\widehat{\text{(Rapid Naming of Letters)}} = 56.38 + \text{Gender}(7.86) + \text{Handedness}(1.64) + \text{IQ}(-.19) + \text{Socioeconomic Status}(.39) + \text{Horizontal Planar Coefficient}(-8.54)$$

The regression equation created was not significant ($\underline{F}$ (5, 41)= 1.21, p = .33) and the Adjusted R^2 is low at .15. Therefore horizontal planar asymmetry does not predict the ability name letters rapidly. Thus, hypothesis 3:3 is not supported by this analysis.

Bonferroni Adjustment. A Bonferroni adjustment was applied to maintain the familywise Type I error at $\alpha = .05$ for research question 3. The equation for the rapid naming family was as follows: $.05 / 3 = .017$. None of the analyses were significant.

Summary of Research Question 3. Leftward horizontal asymmetry of the planum temporale was expected to predict rapid naming skills. However, none of the three regression equations within the rapid naming family was significant. Thus, research question 3 was not supported.

Power Analysis

The largest total R^2 for any hypothesis tested was .38 (Table 12). The model from which this R^2 was derived had 55 participants. A multiple correlation power analysis with five predictors was performed for a total $R^2 = .38$ at $\alpha = .05$ with 55 participants. The power obtained was .99, a figure that is excellent.

The Rapid Naming construct family had fewer cases and a much smaller R^2. A multiple correlation power analysis with five predictors was performed for a total $R^2 = .19$ at $\alpha = .05$ with 41 cases. The power obtained was .50, a figure that is low. However, if more of the variance had been explained by this construct family, and the power analysis conducted with these parameters (i.e., more variance explained by the model but the same *n*), there was sufficient power. For example, a multiple correlation power analysis with five predictors was performed for a total $R^2 = .38$ at $\alpha = .05$ with 41 cases, the power obtained is .93, which is excellent. Power apparently was sufficient had the model explained more variance.

Table 20

Power Analysis

$R^2 = .38$	5 Predictors	$n = 55$	Power = .99
$R^2 = .19$	5 Predictors	$n = 41$	Power = .50
$R^2 = .38$	5 Predictors	$n = 41$	Power = .93

Table 21

Summary of Hypothesis Testing

Construct Family	Predictor Variable	Control Variables Adjusted R^2	Planar Coefficient Adjusted R^2	Change	p value
Phonemic Awareness	LAC	.30	.29	-.01	.0003
	Elision	0	.02	.02	NS
	Incomplete Words	.21	.21	0	.0036
				Bonferroni Adjustment: .05 / 3 = .017	
Emergent Reading	Letter-Word ID	.12	.32	.20	.0002
	Word Attack	.02	.06	.04	.16
	Passage Comprehension	.15	.23	.08	.0032
	ERSI	.16	.25	.09	.0016
				Bonferroni Adjustment: .05 / 4 = .0125	
Rapid Naming	Colors	.09	.08	-.01	NS
	Letters	.01	.03	-.02	NS
	Numbers	-.05	-.07	X	NS
				Bonferroni Adjustment: .05 / 3 = .017	

CHAPTER 5
DISCUSSION

The purpose of this study was to provide additional information as to the influence of neuroanatomy on young children's early reading skills. Specifically, relationships between the degree of asymmetry in the horizontal planum temporale and phonemic awareness, emergent reading skills, and rapid naming skills were examined.

The area of the left planum temporale typically is longer than the area of the right planum temporale and is associated with language function (Geschwind & Levitsky, 1968; Best, 1988; Foundas et al., 1994; Plante et al., 1994). The horizontal planum temporale also has been associated with phonemic awareness (Leonard et al., 1996) and the use of phonemes in language (Damasio et. al, 1992). Longitudinal studies have found a relationship between phonemic awareness and later reading ability (Snider, 1997; MacDonald et al., 1995; Torgesen et al., 1994; Salonen et al., 1998; Lundberg et al., 1980). Based on previous research (Leonard et al., 1996), children with more advanced phonemic awareness and emergent reading skills were expected to have a greater degree of leftward planar asymmetry than children whose phonemic awareness, emergent reading skills, and rapid naming abilities were less developed.

Research Question 1: Phonemic Awareness

The horizontal planar coefficient (i.e., leftward horizontal planar asymmetry) was hypothesized to be related positively with phonemic awareness skills. The phonemic awareness research question was tested using three explanatory multiple regression

equations. The independent variable was the horizontal planar coefficient and the dependent variables were the Lindamood Auditory Conceptualization Test (LAC) (e.g. a measure of phoneme manipulation), Elision Task (e.g., a measure of phoneme manipulation), and the Incomplete Words subtest (e.g., a measure of auditory closure).

Hypothesis 1:1 Elision Test (Phoneme Manipulation)

The horizontal planar coefficient was hypothesized to be positively related with the ability to manipulate phonemes, as measured by performance on the Elision test. The relationship between the horizontal planar coefficient and the ability to manipulate phonemes was not significant.

Hypothesis 1:2 Lindamood Auditory Conceptualization Test (Phoneme Manipulation)

The horizontal planar coefficient was hypothesized to be positively related with the ability to manipulate phonemes, as measured by performance on the LAC. While the equation was significant, only gender and IQ predicted the ability to manipulate phonemes. Collectively, they explained 30% of the variability in the ability to manipulate phonemes.

Hypothesis 1:3 Incomplete Words

The horizontal planar coefficient was hypothesized to be positively related with auditory closure for missing phonemes as measured by the Incomplete Words subtest from the Woodcock-Johnson Psychoeducational Battery–Revised (WJ-R). The equation was significant. However, only IQ, a control variable, predicted of auditory closure for missing phonemes. The control variables, particularlay IQ, explained 21% of the variability in auditory closure for missing phonemes.

Research Question 1 Discussion

Language function has long been associated with leftward asymmetry of the planum temporale (Best, 1988; Foundas et al., 1994; Plante et al., 1991). Children with damage to the posterior perisylvian region has been associated with disruptions in the ability to combine phonemes into words and to select the most appropriate word for the context (Damasio & Damasio, 1992).

Prior research had suggested a relationship between the planar coefficient and phonemic awareness (Leonard et al., 1996) and the use of phonemes in language (Damasio et al., 1992). Few studies focusing on relationships between phonological awareness and the planum temporale were located in the literature. A closer inspection of the data reveals that, although the ability to manipulate phonemes and auditory closure for missing phonemes (i.e., the LAC and the Incomplete Words test) produced significant results, the variance explained can be attributed to the collective contribution of gender and IQ. More specifically, 30% of the variance in the phoneme manipulation task is attributable to the control variables, particularly gender and IQ.

Handedness and SES have no apparent relation with the horizontal planar coefficient or phonemic awareness. Gender and IQ predict a significant amount of variability in phoneme manipulation (i.e., LAC) as the horizontal planar coefficient was not a significant predictor of this skill. Therefore, children's ability to manipulate phonemes as measured by the LAC seemingly is influenced more by their IQ and gender than their horizontal planar coefficient.

The LAC is a novel task for most children and the relationship between the LAC and IQ is not surprising. The LAC requires children to recognize that colored blocks

represent sounds, demonstrate with the colored blocks novel words spoken by the examiner, and manipulate the blocks to represent phoneme changes (i.e., 'pip' to 'pap'). The level of difficulty presented by the task may introduce construct irrelevant-variance in the form of construct irrelevant difficulty (Messick, 1995). By IQ being a significant predictor of LAC performance, it suggests that this task may draw heavily on fluid-reasoning ability. Brighter children may use their advanced problem-solving and reasoning skills to understand and complete this novel task, that may baffle their less endowed peers.

Gender, Handedness, IQ, SES, and leftward asymmetry of the horizontal planum temporale were not related with the ability to manipulate phonemes as measured by the Elision task. The Elision task is a much simpler task than the LAC and is presented in the form of a "word game." Although this task is novel to most children, it requires less higher level reasoning skills than the LAC and is presented verbally.

IQ was a significant predictor of variability in auditory closure for missing phonemes (i.e., Incomplete Words). Handedness, gender, SES, and the horizontal planar coefficient have no apparent relationship with this skill. Children's ability to form words with phonemic segments missing seemingly is influenced more by their IQ than their horizontal planar coefficient.

An inspection of the correlation matrix for the phonemic awareness family reveals that phoneme manipulation (i.e., LAC) and auditory closure for missing phonemes (i.e., Incomplete Words) were highly correlated with IQ. In addition, the two phoneme manipulation tasks, the LAC and Elision tests, also were highly intercorrelated with each other.

The finding that IQ was a significant predictor of phoneme manipulation (i.e., LAC) and auditory closure for missing phonemes (i.e., Incomplete Words) is consistent with a substantial number of studies found in the literature documenting relationship between IQ and academic achievement (Sattler, 1992; Hernstein & Murray, 1994; Carver, 1990; Cornwall, 1992).

The level of phonemic awareness skills assessed by the instruments administered may have been too advanced for the young children in this study. The implications of this advanced level of difficulty are discussed in the limitations section.

Research Question 2 Emergent Reading

The horizontal planar coefficient (i.e., leftward asymmetry of the horizontal planum temporale) was hypothesized to be related positively with emergent reading skills among young children. The emergent reading research question was tested using four explanatory multiple regression equations.

The independent variable was the horizontal planar coefficient and the dependent variables included the ability to identify letters and words, reading of nonsense words, passage comprehension, and an inventory of basic reading skills. These four variables comprise the emergent reading family.

Hypothesis 2:1 Letter-Word Identification

The horizontal planar coefficient was hypothesized to be positively related with the ability to read letters and words as measured by the Incomplete Words subtest. The horizontal planar coefficient and the control variables jointly explained 32% of the variability in the ability to read letters and words.

Hypothesis 2:2 Reading of Nonsense Words

The horizontal planar coefficient was expected to be associated with the ability to read phonetically regular nonsense words as measured by the Word Attack subtest. The relationship between the horizontal planar coefficient and the ability to read phonetically regular nonsense words was not significant.

Hypothesis 2:3 Basic Reading Skills

The horizontal planar coefficient was expected to be associated with basic reading skills, as measured by the ERSI. The horizontal planar coefficient and the control variables explained a significant amount (i.e., 25%) of the variance in basic reading skills.

Hypothesis 2:4 Passage Comprehension

The horizontal planar coefficient was expected to be associated with reading comprehension skills as measured by the passage comprehension subtest. The horizontal planar coefficient and IQ were significant predictors, collectively explaining 23% of the variability in reading comprehension ability.

Research Question 2 Discussion

The leftward asymmetry of the horizontal planum temporale was hypothesized to be positively related with emergent reading skills. Longitudinal studies have found a predictive relationship between phonemic awareness and later reading ability (Snider, 1997; Mac Donald & Cornwall, 1995; Salonen et al., 1998; Lundberg et al., 1980). Pre-reading preschool children who showed signs of emergent reading ability demonstrated higher phonemic and phonological awareness skills than their same aged peers (Bowey, 1994). Studies focusing on relationships between emergent reading skills and the planum temporale could not be located. Because relationships in the literature between

phonological processing and reading skills are well established (Snider, 1997; MacDonald & Cornwall, 1995; Torgesen et al., 1994; Salonen et al., 1998; Lundberg et al., 1980) horizontal planar asymmetry was hypothesized to be positively related with emergent reading skills. This hypothesis was partially confirmed in this present study with three of the four equations testing the Emergent Reading hypothesis being significant.

One of the most compelling finding within the emergent reading family was the amount of variance (i.e., 20%) explained by the horizontal planar coefficient in the prediction of letter-word identification skills. The ability to identify letters and read common sight words was predicted by leftward horizontal planar asymmetry. Recall that the total amount of variance explained by the horizontal planar coefficient and the control variables was 32%, with 12% of the variance explained by the control variables. Thus, 20% of the variance within the model was explained by the horizontal planar coefficient. This finding lends support to the theory that a specific biological region within the brain, the horizontal planum temporale, is associated with identifying letters and sight words. Planar asymmetry appears to partially predict three reading skills: the identification of letters and words, comprehension, and basic reading skills.

The amount of variance contributed by the horizontal planar coefficient in hypothesis two is relatively small (i.e., 8 to 20%). Reading is a complex task that requires the synthesis of many cognitive abilities and skills as well as noncognitive qualities (e.g., interest, motivation, persistence). Furthermore, the neurobiological processes impacting reading are likely to be dispersed broadly throughout the brain and not confined to one specific region. Studies investigating the culminating effects of

multiple anatomical structures and their relationship to reading disabilities (Leonard, Eckert, Lombardino, Oakland, Kranzler, Mohr, King, & Freeman, 2001) and schizophrenia (Leonard, Kuldau, Breier, Zuffante, Gautier, Heron, Lavery, Packing, Williams, & DeBose, 1999) have substantiated this hypothesis.

The horizontal planar coefficient did not predict the ability to read phonetically regular nonsense words as measured by the Word-Attack subtest. Children must apply phonemic and structural analysis skills when pronouncing phonetically regular nonsense words. In this study, the measure of the ability to read phonetically regular nonsense words was categorized as a measure of basic reading ability. Reliance on an individual's phonemic awareness and decoding skills to accurately read phonetically regular nonsense words may cloud the nature of the task. That is, attempting to decode may be measuring multiple qualities, including phonological recoding in lexical access, phonetic recoding to maintain information in working memory, phonemic awareness, and ultimately the ability to produce words they have never seen or heard. Furthermore, the decoding of phonetically regular nonsense words requires persons to accurately pronounce the word presented. The measure used to assess the reading of nonsense words appears to require a number of cognitive processes and to rely more heavily on phonological processing skills than the other emergent reading tasks.

Thus, in reference to research question one, phonemic awareness tasks were not associated with horizontal planar asymmetry. The ability to read nonsense words (i.e., Word-Attack), which is highly dependent on strong phonological processing skills, also may indicate that the processes involved in phonological processing are dispersed more broadly and in several regions of the brain. The horizontal planar coefficient appears to

be associated with sight word reading and reading comprehension rather than the subcomponent set of phonemic awareness skills.

Research Question 3 Rapid Naming

The occurrence of deficits in naming-speed have been found in persons with severe reading disabilities (Wagner et al., 1999; Wolfe, 1997; Felton et al., 1990). Leftward horizontal planar asymmetry was expected to be positively related with the ability to name objects rapidly. This hypothesis was not supported through tests by three explanatory multiple regression equations. Leftward horizontal planar asymmetry was not associated with rapid naming. The rapid naming of colors, numbers, and letters requires efficient retrieval of phonological information from long-term memory. While reading, children must retrieve phonemes associated with letters. Efficiency in this retrieval process is necessary to successfully decode words. Current findings suggest mechanisms associated with the long-term retrieval of phonological information are not located in the horizontal planum temporale.

An inspection of the rapid naming family correlation matrix reveals that the three areas investigated (i.e., naming colors, letters, and numbers rapidly) are highly intercorrelated. The relationship between naming numbers and letters rapidly is particularly strong ($r = .80$). The strong relationship between naming letters and numbers rapidly may be due to their relying on similar cognitive processes. Furthermore, in that the correlation between naming colors rapidly and naming letters and numbers is somewhat lower (i.e., the mid. 60s), the naming of colors rapidly may rely on somewhat different cognitive processes. The rapid naming of letters and numbers has been found to

be more predictive of reading skills than the rapid naming of colors (Wagner, Torgesen, & Rashotte, 1999).

Other Findings

Four variables (i.e., gender, handedness, intelligence, and socioeconomic status) were controlled through statistical analyses. Strong links between intellectual ability, academic achievement, and socioeconomic status are well established in the literature. Gender and handedness have been associated with language function and cortical volume.

Gender

Brain weight and volume are greater in males than females at all ages (Dekaban & Sadowsky, 1978; Caviness et al., 1997; Reiss et al., Giedd, 1997; Giedd et al., 1996). Gender, which was controlled in the analyses, was hypothesized to be related to the horizontal planar asymmetry coefficient and thus predict phonemic awareness, emergent reading, and rapid naming skills.

Gender was not correlated with the horizontal planar asymmetry coefficient. Gender was a significant predictor in only one of the ten analyses (i.e., phoneme manipulation as measured by the Lindamood Auditory Conceptualization Test). Gender combined with IQ to predict 30% of the variance in the ability to manipulate phonemes as measured by the LAC. Thus, gender did not contribute significantly role to the prediction of phonemic awareness, emergent reading, or rapid naming skills.

Controlling for gender in analyses may not be necessary when studying the language-associated cortical regions. The volume of language-associated cortical regions was found to be proportionally larger in females than males. That is, females had significantly smaller brains but similar sized language-associated brain regions (Harasty

et al., 1997). In particular, the left and right superior temporal gyri occupied 18% more of the total brain in females than in males. The authors concluded that the planum temporale accounted for most of the increased volume within the superior temporal gyrus in female brains.

In the current study, gender did not predict phonemic awareness, emergent reading, or rapid naming. The lack of relationship provides further support for not controlling gender in anatomical studies of language-associated cortical regions, like the planum temporale.

Handedness

Handedness can impact neuroanatomical development and functioning. Left-handedness is more frequent in males, and males comprise the majority of those diagnosed with autism, dyslexia, stuttering and other developmental disorders (Geschwind & Galaburda, 1985; Kinsbourne, 1988).

The lateralization of language functioning to the left hemisphere almost always occurs in right-handed individuals. The lateralization of language functioning in left-handed individuals is less certain (Harris & Carlson, 1988). The left hemisphere is lateralized for language in about 60% to 70% of left-handers, with the remaining 30% to 40% being lateralized rightward or bilaterally (Harris & Carlson, 1988). Handedness was controlled in the study.

The classification system used in this study resulted in a handedness quotient. Participants were classified as right-handed if they wrote with their right hand and had a quotient of .75 or greater. All others were classified as non-right. Thus, all participants not falling in the strongly right-handed category were classified as non-right handed.

That is, the strongly left-handed participants were combined with ambidextrous and persons who might write with their right hand but do other tasks (e.g., throw or catch) left-handed. Although this quotient provides a broader picture of handedness by not limiting it to the writing hand, it may cloud the effect of handedness due to the way the categories were formed.

In the present study, handedness did not contribute to the variability in any analyses, that is, handedness did not predict phonemic awareness, emergent reading, or rapid naming skills.

Intelligence

Reading is a complex task that requires the synthesis of many cognitive abilities and skills as well as noncognitive qualities (i.e., interest, motivation, persistence). Furthermore, the neurobiological processes impacting reading are likely to be dispersed broadly and not confined to one specific region. Intelligence, too, is a robust quality and does not reflect specific and isolated skills. Intelligence may be the best predictor of a person's ability to read phonetically regular nonsense words, reading comprehension, spelling, prose passage speed, and reading accuracy scores (Carver, 1990; Cornwall, 1992). Intelligence was controlled in this study to help ensure children's performance was not merely a result of their intellectual ability.

Intelligence explained a significant amount of variance in the study's five significant equations and contributed the majority of the variance in four. Intelligence was a significant contributor to the variance associated with phoneme manipulation, auditory closure for missing phonemes, sight word reading skills, reading comprehension, and early reading skills.

Intelligence correlated significantly with several phonemic awareness and emergent reading skills (i.e., Lindamood Auditory Conceptualization Test, Incomplete Words, Letter-Word Identification, Word Attack, Passage Comprehension, Early Reading Screening Inventory). As suggested in the literature (Carver, 1990; Cornwall, 1992; Sattler, 1992; Herrnstein & Murray, 1994), intelligence predicted academic skills in this study.

Socioeconomic Status

Socioeconomic status (SES) is strongly linked with intellectual ability as well as reading skills and other achievement areas. Thus, it was controlled in this study. The correlation between a family's SES and children's intelligence test scores average about .33 (Sattler, 1992; Andersson et al., 1996). Home environment and SES predict children's intelligence most strongly (Molfese et al., 1997). Socioeconomic status is associated with sensitivity to phonological structure (Wallach et al., 1977), the ability to identify words, and to read phonetically regular nonsense words (Cornwall, 1992).

Surprisingly, SES did not contribute to the prediction of the variance in the reading skills. In other studies, children from middle SES backgrounds have been found to have more highly developed phonological structure, more advanced pre-reading skills, and use more standard phonological and grammatical components than peers in lower socioeconomic groups (Cornwall, 1992; Dickinson & Snow, 1987; Ratusnik & Koenigsknecht, 1975; Wallach et al., 1977). However, SES correlated significantly ($p \leq .01$) with naming colors rapidly ($r = .39$). Identifying colors is one of the first early academic skills learned by preschoolers and is often passively taught in the home by a child's parents. Middle SES children have been found to have an advantage over their

lower SES counterparts in many academic and language areas. It is possible that children from middle SES families have more experience with the names of colors and this familiarity leads to their advantage (i.e., automaticity) during the rapid naming task. The teaching of letters and numbers may be relegated as part of the instructional domain of the school by parents. Furthermore, children in the present study ranged from five to seven years of age, had not yet entered the first grade, and were by design in the early stages of reading instruction. Because the participants were in the beginning stages of reading acquisiton, the middle SES children may not have acquired a level of automaticity for numbers and letters distinguishable from their lower SES peers at the time of the assessment.

The effectiveness of early childhood intervention programs has been studied extensively (Lazar & Darlington, 1982; Schweinhart, Barnes, & Weikart, 1993; Schweinhart & Weikart, 1983). Children in the present study were beginning their school careers and may have been demonstrating the effects of a quality preschool program they had attended previously. Participation in a quality early intervention program has been associated with increased academic achievement, improved intelligence scores in the early grades, higher levels of schooling, higher graduation rates, significantly fewer placements in special education, and fewer retentions (Lazar & Darlington, 1982; Schweinhart, Barnes, & Weikart, 1993; Schweinhart & Weikart, 1983). Lower SES children typically would be expected to perform lower than their higher SES peers. Information regarding the preschool experiences of the participants was not collected. However, many of the low SES children in the sample may have participated in a quality

preschool program. The effects of the early intervention program may have "washed out" the expected SES effects.

The Four Factor Index of Social Status (Hollingshead, 1975) was used to provide an index of SES based on parent education and occupation. Estimates of SES ranged from the lowest groups (i.e., unskilled laborers and service workers) to the highest (i.e., major business owners and professionals) levels within all three families. The occupation component is based on job title and is divided into a nine-level scale. This scale does not represent the actual income earned by the parents but estimates it based on their occupation.

A relationship may have been found if the actual family income had been included rather than an estimate. Family income correlated more strongly with intelligence among five year-olds than did maternal education, ethnicity, and female headship of household (Duncan et al., 1994). Factors not included in this scale (i.e., savings, inheritance, investment income, a second job, or excessive debt) could increase or reduce the family's income and were not accounted for in the study.

Summary

This study examined relationships between horizontal planar asymmetry and phonemic awareness, emergent reading skills, and the ability to rapidly name objects in young children just prior to or in the beginning stages of reading instruction. Horizontal planar asymmetry was related to the ability to identify words and letters, reading comprehension, and basic reading skills. IQ correlated significantly with all of the emergent reading tasks and with two phonemic awareness tasks.

Continued research into relationships between the brain and reading skills may yield information of neurobiological indicators for reading and reading deficiencies. Ultimately, one may be able to screen young children for neurobiological indicators indicative of reading disorders prior to their manifestation. If a predisposition for reading disorders is recognized anatomically, intensive primary interventions may be provided to children to reduce the chances or magnitude of the emerging disorders. Ultimately, very specific remediation techniques can be used based on the location of the neurobiological indicator.

Limitations

One possible explanation for the lack of significant results within the phonemic awareness family may be that the three tasks used to assess the development of phonological skills were too advanced for children in the early stage of phonological development. The three tasks comprising the phonemic awareness family assess the two most advanced skills within the five levels of phonemic awareness (Adams, 1990; Snider, 1997), phonemic segmentation and phoneme manipulation. Phoneme manipulation was assessed with the LAC and Elision tests. Although there is score variability within the individual tests, the phoneme manipulation scores obtained by children in the sample were well below the maximum score. Future studies should include less complex phonological processing tasks (i.e., a test of rhyming ability or grouping words by sound).

The maximum obtainable score on the LAC is 100. The average LAC score obtained by children in the sample was 38, with scores ranging from 20 to 76. The maximum obtainable score on the Elision task is 25. The average Elision score obtained by children in the sample was eight, with scores ranging from three to 19. Auditory

closure for missing phonemes was measured with the Incomplete Words subtest of the WJ-R. This test is on a standard score scale with a mean of 100 and a standard deviation of 15. The average Incomplete Words score was 98, with scores ranging from 73 through 133. Children in the sample, on average, performed at the level expected given their age on the Incomplete Words subtest.

Children who are bright may have mastered these skills while their same-aged peers of average intellectual ability are acquiring them. That is, the tests may not have been sensitive enough, or at the appropriate skill level (i.e., the basal was not low enough) to assess phonological awareness in some young children. Furthermore, the phonemic assessment tasks, as they were presented, are novel to most children. Brighter children may use their advanced problem-solving and reasoning skills to understand and complete these novel tasks, that may baffle their less endowed peers.

There may simply be no relationship between phonological awareness and the horizontal planum temporale. The neurobiological processes impacting reading are likely to be dispersed broadly and not confined to one specific region. The areas responsible for phonemic awareness may be simply located elsewhere or be highly dispersed throughout the brain. Finally, the qualities measured by these tests may be more sensitive to environmental influences such as instruction or exposure to print and to language than anatomy.

Validity is the degree to which evidence and theory support interpretations of test scores entailed by proposed uses of tests (Standards for Educational and Psychological Testing, 1999). Construct underrepresentation and construct-irrelevant variance are the two major threats to construct validity (Messick, 1995).

Construct underrepresentation refers to the degree to which a test fails to capture important aspects of the construct (Standards for Educational and Psychological Testing, 1999). Construct underrepresentation occurs when a test fails to include important dimensions or facets of a construct, resulting in restricted meaning of test scores because the test does not adequately sample content, utilize some psychological processes, or elicit behaviors that are encompassed by the intended construct (Messick, 1995; Standards for Educational and Psychological Testing, 1999). The use of one test to measure a construct is likely to provide an underrepresentation of the construct as well as error variance. Thus, construct validity will be lower in research that uses one test rather than two or more tests to assess a construct (Cook & Campbell, 1979). Each construct family was tested with a minimum of three indices of the proposed construct (i.e., Phonemic Awareness- 3 assessments, Emergent Reading – 4 assessments, Rapid Naming – 3 assessments) in order to reduce the threat of construct underrepresentation. This attempt to reduce the threat of construct underrepresentation appears to have increased the threat of construct-irrelevant variance.

Construct-irrelevant variance refers to the degree to which test scores are affected by processes that are extraneous to the intended construct (Standards for Educational and Psychological Testing, 1999). Examples include tests that provide excessively broad assessment of the intended construct and contain excess variance associated with their assessment of other constructs. Method variance (e.g., response sets or guessing propensities) also affects the responses in a manner irrelevant to the construct (Messick, 1995).

With regard to the Emergent Reading family, 3 out of 4 hypotheses were significant. The Word-Attack test was included as a measure of Emergent Reading as it is a synthesis of reading skills. A child must apply phonemic and structural analysis skills to read phonetically regular nonsense words. All of the words presented followed the patterns of regular English pronunciation and spelling. Leftward asymmetry of the horizontal planum temporale did not predict the ability to read phonetically regular nonsense words as measured by the Word-Attack test.

In addition to being a test of novel sight word reading, the Word Attack test also is considered to be a test of phonemic awareness. Categorizing the Word Attack subtest as a measure of emergent reading appears to have contributed to construct-irrelevant variance. Although the Word Attack test can be categorized theoretically as a measure of sight-word reading skill and reduces the threat of construct underrepresentation, it did not satisfy the empirical criteria (e.g., statistical significance) and suggests this classification resulted in construct-irrelevant variance for the emergent reading family.

Horizontal planar asymmetry did not predict phonemic awareness. In retrospect, the Word-Attack test may have been better placed in the phonemic awareness category as it is sometimes classified as a measure of phonemic awareness.

The sample sizes ranged from 41 to 58. Significant results may have been obtained if the sample size had been larger. These sample sizes are relatively low for behavioral science research, yet higher than those typically found in neuroscience research. Larger sample sizes contribute to the probability of higher power. Thus, the lower power associated with relatively low sample sizes accounts in part, for a lack of significance in the data.

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BIOGRAPHICAL SKETCH

Sharyl Ann Williams was born on November 8, 1972 in Bradenton, Florida. She graduated Magna Cum Laude and Phi Beta Kappa in 1994 from Stetson University in DeLand, Florida where she earned her B.A. in psychology. While at Stetson, she completed her undergraduate thesis in the area of public opinion of disease sufferers based on how the disease was contracted. As an undergraduate student, Sharyl interned at a 12-step drug treatment facility for prisoners. Following graduation, she worked at Northside Mental Health Hospital in Tampa, Florida as a case manager for chronic mentally ill adults. Upon entering the School Psychology program in the fall of 1995, she became the fourth member of her family to seek higher education at the University of Florida. Her master's thesis studied the support factors contributing to mothers' commitment to an intervention program in the Gaza Strip during the Intifada. Sharyl received her M.A.E. from the University of Florida in August 1998 and became a doctoral candidate in November of 1998. She completed her pre-doctoral internship at the Florida State University Multidisciplinary Center in July of 2000. Sharyl lives in Atlanta, Georgia and is employed by the Clayton County School Board as a school psychologist.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Thomas D. Oakland, Chair
Professor of Educational Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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